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ENVIRONMENTAL HEALTH SERIES
AIR POLLUTION

A Pilot Study of AIR POLLUTION IN JACKSONVILLE, FLORIDA

U. S. DEPARTMENT OF HEALTH, EDUCATION, AND WELFARE
Public Health Service

STUDY OF AIR POLLUTION IN JACKSONVILLE, FLORIDA

A PILOT STUDY OF AIR POLLUTION IN JACKSONVILLE, FLORIDA

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Public Health Service

Division of Air Pollution

Cincinnati 26, Ohio

April 1963

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Public Health Service Publication No. 999-AP-3

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ABSTRACT

The objectives of this pilot study were to develop a preliminary evaluation of air pollution in Jacksonville and to determine whether fluoride and sulfur dioxide concentrations were sufficient to cause damage to vegetation that had occurred in the area. The study consisted of an emission inventory, a meteorological investigation, an intensive short-term study of downtown Jacksonville, and an industrial area study. Pollutants sampled for included sulfur dioxide, oxidants, nitrogen dioxide, carbon monoxide, hydrogen sulfide, fluorides, and suspended particulates. During the study fluoride concentrations were high enough in certain parts of the city to cause damage to sensitive plants; sulfur dioxide and oxidants were also present at significant levels. Results of the study also indicated that photochemical smog is produced over Jacksonville, that pollutants from Jacksonville are transported across the St. John's River, and finally, that several pollutants constitute a potential problem in the city and should be evaluated further.

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A PILOT STUDY OF AIR POLLUTION IN JACKSONVILLE, FLORIDA

SUMMARY

GENERAL

National attention was focused on air pollution in Jacksonville, Florida, in 1948, when nylon apparel disintegrated on local residents; the cause: air pollution. In the years that followed, an ever increasing number of complaints were registered regarding air pollution in the Jacksonville-Duval County area. In the spring of 1961, damage to vegetation occurred; the prime suspect: air pollution.

Dr. Wilson T. Sowder, then Florida State Health Officer, on May 31, 1961, requested of Dr. W. H. Aufranc, Regional Health Director, United States Public Health Service, Region IV, Atlanta, that a pilot study of the Jacksonville air pollution problem be conducted jointly by the Public Health Service, the Florida State Board of Health, and the Jacksonville City Health Department. In response to this request, the Technical Assis- Branch of the Division of Air Pollution of the Public Health Service sent a five-man team to Florida to work with State Board of Health and City Health Department personnel in evaluating air pollution problems in the Jacksonville area. During the initial stages of this evaluation, State and city personnel were to be trained in survey techniques, so that future programs could be carried out with a minimum of Federal assistance.

The objectives of this pilot study were (1) to develop a preliminary opinion as to whether the city of Jacksonville has a generalized air pollution problem and (2) to determine whether certain pollutants, fluorides and sulfur dioxide, were present in the atmosphere in concentrations capable of producing the damage to vegetation that had been experienced in the Jacksonville-Duval County area.

To accomplish the first objective, a 1-week intensive investigation was carried on in downtown Jacksonville at Hemming Park from August 3 to 10, 1961.

To accomplish the second objective, additional studies were conducted from August 4 to 12, and September 5 to 13, 1961, in the area in which damage to vegetation had occurred. Two fertilizer plants, located in the industrial area of Jacksonville, were not in production during the first phase of this study. Pollutants sampled in this study included fluorides, sulfur dioxide, hydrogen sulfide, nitrogen dioxide, and particulates.

The air quality data collected during these studies indicated that certain air pollutants (fluorides, sulfur dioxide and oxidants) were present in significant levels in the air over Jacksonville.

FLUORIDE

Airborne fluoride concentrations capable of causing damage to sensitive plants under proper growth conditions were found during the study. The data indicated that conditions for transport of objectionable concentrations of airborne fluorides across the St. John's River into the Arlington area do occur.

HYDROGEN SULFIDE

Although no high concentrations of hydrogen sulfide were observed during this study, darkening of lead-base paints and paints containing mercury-base fungicides in the Arlington area subsequent to the study indicates that a problem due to hydrogen sulfide does exist there.

OXIDANTS

Oxidant concentrations observed during this study, although less than those measured in Los Angeles during severe pollution, indicate that photochemical-type smog similar to that produced in the Los Angeles area is being produced in the city of Jacksonville. The maximum oxidant level measured by the phenolphthalin method during August 3 to 10, 1961, was 0.162 parts per million (ppm) by volume (as hydrogen peroxide).

SULFUR DIOXIDE

Sulfur dioxide concentrations observed during the nonheating season in which the study was conducted were generally low. The maximum concentration observed during this study was 0.174 ppm, a value similar to maximums observed in larger cities of the country.[1,2] This high value probably was due to emission of sulfur dioxide from a major source. It can be expected that sulfur dioxide levels would be higher during the winter months in Jacksonville. Major sources of sulfur dioxide may cause periodic occurrence of concentrations higher than those observed, at certain locations in the Jacksonville area, possibly reaching levels that would cause damage to sensitive plants.

CONCLUSIONS

As a result of the urban and industrial area investigations it is concluded that:

1. Photochemical smog is being produced in the air over Jacksonville.

2. Concentrations of fluorides occurred in certain parts of Jacksonville during the study that could cause damage to sensitive plants.

3. Pollutants from the city of Jacksonville are transported across the St. John's River.

INDICATIONS

1. Hydrogen sulfide concentrations were not of the magnitude known to cause discoloration of paints containing lead pigments and/or mercury-base fungicides. Subsequent to the study, an incident of darkening of paints occurred in the Arlington area. Therefore, it is evident that a hydrogen sulfide problem exists in that area.

2. Sulfur dioxide concentrations did not reach levels known to cause damage to vegetation. It appears possible, however, for sulfur dioxide concentrations during the heating season to reach levels capable of causing damage to sensitive plants, particularly in localized areas downwind of major sources of sulfur dioxide.

3. The data collected also indicate that the fine particulates causing soiling and the sulfur dioxide measured at Hemming Park are being emitted to the atmosphere from the same source or sources. A general relationship between wind direction and sulfur dioxide concentrations measured during the industrial area investigation was demonstrated.

RECOMMENDATIONS

Levels of certain air pollutants found during these studies indicate that the Jacksonville-Duval County area has air pollution problems. The following recommendations are therefore made:

1. A full-time air pollution control program should be activated. This program should encompass the area affected by the air environment receiving the pollutants emitted in the Jacksonville-Duval County area. The study conducted in August-September, 1961, demonstrated that pollution from the city of Jacksonville can affect areas outside of the city. Visual observations indicate that meteorological conditions do occur that could transport pollutants from outside the city into the Jacksonville area. The air pollution control program should encompass the area within a distance of 25 miles or more from the city of Jacksonville.

2. The air pollution control program should include further evaluations of air pollutant levels and source emissions, and monitoring of possible effects of air pollutants on plants and property. Such studies are necessary to determine whether progress is being made in protecting the air environment of the Jacksonville area, and whether new air pollution problems are arising.

3. A continuing micrometeorological study should be an integral part of this program. Such a study would not only allow a better understanding of relationships between source emissions and ground level concentrations, but would provide the necessary scientific data required for planning proper utilization of the air environment.

4. Since completion of this study, certain of the industrial plants have instituted additional control procedures, and have made operational changes to decrease pollutants emitted to the Jacksonville atmosphere. A repeat of the study conducted in the industrial area would provide information on the effectiveness of these control procedures and process changes.

INTRODUCTION

BRIEF DESCRIPTION OF THE AREA

Greater Jacksonville straddles the St. John's River at a point approximately 15 miles from the Atlantic Ocean. Eighty-two percent of Duval County's 1960 population of 455,411 live in the 130-square-mile area classed as urban by the U. S. Bureau of the Census.[3] Over 200,000 individuals live in the city of Jacksonville proper.

Jacksonville, the county seat and one of the larger cities of the State, is a manufacturing and transportation center as well as a seaport. The deep water port at Jacksonville, and its location at the hub of Florida's railway and highway systems, has made the city an important distribution center for Northeast Florida and Southeast Georgia.

Major industries are food processing, pulp and paper, chemicals, and shipbuilding and repair. Manufacturing is quite diversified, with no one industry accounting for over 15 percent of the county's manufacturing employment.[4]

ORIGIN AND PURPOSE OF THE STUDY

Air pollution in Jacksonville received national recognition in 1948 with the famous incident in which nylon blouses and stockings disintegrated on the wearers. Evidence pointed to air pollutants emitted in burning of high sulfur residual fuel oil as the cause. Since that date, public interest in air pollution problems has grown to the extent that in 1960 over 1700 complaints of odors, dust, soot, smoke, and damage to property and vegetation were received from Duval County residents by the city, county, and state public health agencies.

In the spring of 1961, severe vegetation damage occurred in the residential areas on both sides of the St. John's River. The center of the damaged area was the industrialized section located in the East Jacksonville waterfront area. Preliminary investigations by the State Board of Health, the Jacksonville City Health Department, and the State Agricultural Extension Service indicated that the probable cause of the damage was one or a combination of the air pollutants (particularly fluorides and sulfur dioxide) thought to be present in that area.[5] Figures 1 and 2 indicate the geographical distribution of elevated concentrations of fluorides and sulfates in vegetation (althea leaves) sampled. Following an investigation of the affected area in June of that year, Dr. C. S. Brandt, an authority on air pollution damage to vegetation, reported in part:

Figure 1. Distribution of fluoride in Althea leaves collected May 11, 1961 (mg. F^-/gm. dry leaf).

Figure 2. Distribution of sulfate in Althea leaves collected May 24, 1961 (mg. $SO_4^{=}$/gm. dry leaf).

" . . . Since there had apparently been considerable recovery since the initial development of the symptoms, there is some uncertainty as to actual cause and severity. However, sufficient injured material remained showing characteristic fluoride burn to implicate this agent. The analytical data that you have on hand would tend to confirm this observation.

"While there was no evidence, at the time of my visit, of acute sulfur dioxide injury, your analytical data of markedly elevated sulfate levels (in vegetation) in the area and the description of the early 'kill' lead me to suspect that this may have been a contributory factor to some of the early dramatic effects.

"The bleached type of injury now being seen in this area on various species, is not readily identifiable as characteristic of any single known air pollutant. I am inclined to believe that it represents a physiological stress on the plant of which air pollution in the form of fluoride, sulfur dioxide, and possibly mineral salts, is a contributing factor . . . . "[6]

These preliminary investigations implicated several pollutants as probable contributors to the vegetation damage in Jacksonville in 1961. Virtually no ambient air pollution samples had been collected in the Jacksonville area except the bi-weekly particulate samples for the Public Health Service's National Air Sampling Network at the State Board of Health Building near downtown Jacksonville. There were insufficient trained personnel and specialized air pollution sampling devices available to governmental agencies operating in the Jacksonville area to conduct the air sampling program necessary to adequately characterize the air quality of Jacksonville.

Consequently, on May 31, 1961, the State Health Officer, Dr. Wilson T. Sowder, requested technical assistance from the Public Health Service in a cooperative air quality study to be conducted jointly by the Public Health Service, the Florida State Board of Health, and the Jacksonville City Health Department. In the latter part of July 1961, four members of the Air Pollution Training Staff and one of the Technical Assistance Staff of the Public Health Service, Division of Air Pollution, were assigned to participate in this study.

The first objective was to train local personnel in air pollution survey methods, so that they could carry out future sampling and analytical programs. This was accomplished during the initial phase of the pilot study by a special short course in survey techniques and subsequent on-the-job training during the early part of the study. The objectives of the pilot study were twofold:

1. to develop a preliminary opinion as to whether the city of Jacksonville has a generalized air pollution problem.

2. to determine whether fluorides and sulfur dioxide were present in the atmosphere in concentrations capable of producing the damage to vegetation that had been experienced in the Jacksonville-Duval County area.

This report, therefore, describes the pilot study conducted during August and September of 1961 in the Jacksonville-Duval County area, including (1) The emission inventory, conducted concurrently with the sampling studies to determine the kind and amount of pollutants emitted to the atmosphere in this area; (2) an investigation of the meteorological conditions of the area; (3) the short term intensive investigation conducted in Hemming Park; and (4) the industrial area study of pollutants suspected of causing plant damage.

GPO 802-899-2

INVENTORY OF EMISSIONS

To better evaluate existing and potential area-wide air pollution problems in the Jacksonville area, an emission inventory was carried out. Approximately 50 of the largest industrial and municipal sources of pollution and 200 commercial establishments were contacted by personal visits, questionnaires (see Appendix) and/or telephone. The information obtained, plus the cumulative past experience of other investigators as published in the literature, provided a basis for a reasonable estimate of pollution emissions.

The classifications and types of sources, and references used to estimate these emissions are shown in Table 1. Local sources are defined as sources that are not uniformly distributed throughout the area. As such, these sources potentially have the greatest effect on areas adjacent to them. They also influence the general community atmosphere, especially under certain meteorological conditions. Area sources are those sources that are distributed throughout the study area. Classifications of contaminants are listed in Table 2; the findings of this study are summarized in tables in this section.

The values in this emission inventory are estimates and should not be construed to be absolute. For this reason, all estimates have been rounded off to two significant figures. Equally important is the fact that the Tables do not include all pollutants that are emitted to the air over Jacksonville. Estimates were made only for those classes of pollutants that have been implicated as possibly having an adverse effect on man or his environment and for which emission factors are available. As further investigations are conducted in the field and new findings are published, estimates such as those contained in this report would be listed for a far greater number of pollutants.

ORGANIC GASES

Hydrocarbons

It is estimated that 120 tons of hydrocarbons per day are emitted to the air environment in the Jacksonville area (Table 3). Approximately one-third of these emissions come from transportation sources. In the Jacksonville area the hydrocarbon emission rate of approximately 1 ton per square mile per day approaches the rate estimated in Los Angeles.[8, 15] Hydrocarbons and oxides of nitrogen in sufficient quantities can react in the presence of sunlight to form photochemical smog. This

Table 1. CLASSIFICATION OF SOURCES, AND REFERENCES USED IN ESTIMATING POLLUTANT EMISSIONS

Classification	Source type	References
Local sources	Power generation - power production for municipal and domestic consumption	7, 8
	Incineration - municipal incinerators	7, 8
	Water aeration - municipal plants for removal of hydrogen sulfide from well waters	-
	Industrial combustion	7, 8[a]
Area sources	Commercial - stores, office buildings, hotels, launderies, dry cleaners, gasoline handling and marketing, and bulk petroleum storage operations	7, 9, 10[a]
	Domestic - home heating, cooking, and hot water heating	7, 8, 11, 12[b]
	Transportation - automobiles, diesel vehicles, diesel switch engines	7, 8, 13, 14[c]

[a]References cited used in addition to emission information obtained through emission inventory.

[b]Domestic heating estimates are based on the references indicated. Home heating requirements per housing unit in the winter are estimated to be 80,000 Btu per hour net for a 16-hour day at an assumed central heating efficiency of 80% and an assumed non-central-heating efficiency of 50%. Year-round hot water heating is estimated to be 100,000 Btu per day gross. Year-round heating for cooking is estimated to be 20,000 Btu per day gross.

[c]On the basis of fuel tax figures and the number of heavy trucks registered in Duval County, it is estimated that 11% of the total vehicle miles are traveled by diesel-powered vehicles. A fuel combustion rate of 8 gal/hour was reported for diesel-powered switch engines.

Table 2. CLASSIFICATION OF CONTAMINANTS ESTIMATED IN EMISSION INVENTORY[a]

Major classes of air contaminants	Sub-classes of contaminants	Typical members of sub-classes
Organic gases	Hydrocarbons	Hexane, benzene, ethylene, methane butane, butadiene
	Aldehydes and ketones	Formaldehyde Acetone
	Other organics	Chlorinated hydrocarbons Alcohols
Inorganic gases	Oxides of nitrogen	Nitrogen dioxide Nitric oxide
	Oxides of sulfur	Sulfur dioxide Sulfur trioxide
	Oxides of carbon	Carbon monoxide Carbon dioxide
	Other inorganics	Hydrogen sulfide, hydrogen fluoride Ammonia Chlorine
Particulates	Solid particulates	Dusts, smoke, fumes
	Liquid particulates	Oil mists, entrained liquid droplets

[a]Modification of reference 7.

inventory indicated that the city of Jacksonville has a potential photochemical smog problem.

Aldehydes, Ketones and Other Organic Gases

Estimated emissions of aldehydes, ketones and other organic gases in the Jacksonville area are shown in Tables 4 and 5, respectively. In both cases, there is an expected increase in emission from summer to winter, resulting from the load imposed on the air environment by domestic heating.

INORGANIC GASES

Oxides of Nitrogen

Approximately 93 tons of oxides of nitrogen are emitted per day during the summer months in the Jacksonville area

Table 3. ESTIMATED EMISSIONS OF HYDROCARBONS IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day[a]	% of total estimated emissions[a]	Estimated emissions, tons/day[a]	% of total estimated emissions[a]
Local sources				
Power generation	4.0	3.5	4.0	3.3
Incineration	1.1	0.95	1.1	0.89
Industrial combustion	21.	18.	21.	17.
Industrial processes	24.	21.	24.	20.
Area sources				
Commercial	26.	23.	25.	20.
Domestic	0.28	0.24	9.0	7.3
Transportation	39.	34.	39.	32.
Total	120.	-	120.	-

[a]All estimates rounded to two significant figures.

Table 4. ESTIMATED EMISSIONS OF ALDEHYDES AND KETONES IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	2.9	32.	2.9	19.
Incineration	1.8	20.	1.8	12.
Industrial combustion	3.5	39.	3.5	22.
Industrial processes	0.25	2.7	0.25	1.6
Area sources				
Commercial	0.10	1.1	0.15	0.96
Domestic	0.06	0.66	6.5	42.
Transportation	0.46	5.1	0.46	3.0
Total	9.1	---	16.	---

Table 5. ESTIMATED EMISSIONS OF OTHER ORGANIC GASES IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	13.	25.	13.	18.
Incineration	1.4	2.7	1.4	1.9
Industrial combustion	36.	68.	36.	50.
Industrial processes	1.0	1.9	1.0	1.4
Area sources				
Commercial	0.48	0.91	0.73	1.0
Domestic	0.26	0.49	19.	27.
Transportation	0.61	1.2	0.61	0.85
Total	53.	---	72.	---

(Table 6). It has been estimated that this amount doubles during the winter months because of domestic heating activities. Emission rates of oxides of nitrogen are comparable on a unit area basis to those of other communities experiencing photochemical smog.[15] As was the case in the estimated hydrocarbon emissions, these data indicate that Jacksonville has a potential photochemical smog problem.

Oxides of Sulfur

Estimated emissions of oxides of sulfur for the Jacksonville area are presented in Table 7. During the summer months, 240 tons of oxides of sulfur are emitted to the atmosphere per day. Ninety-nine percent of these emissions are from local sources. It is indicated that problems resulting from oxides of sulfur might occur in areas near these sources.

During the winter months, it is estimated that emissions of oxides of sulfur increase to more than 400 tons per day. This expected increase is due to home heating activities.

OXIDES OF CARBON

Carbon Monoxide

Estimated emissions of carbon monoxide in the Jacksonville area are presented in Table 8. Approximately 98 percent of

Table 6. ESTIMATED EMISSIONS OF OXIDES OF NITROGEN IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	58.	63.	58.	31.
Incineration	0.70	0.75	0.70	0.37
Industrial combustion	20.	21.	20.	11.
Industrial processes	0.06	0.065	.06	0.032
Area sources				
Commercial	0.67	0.72	1.0	0.54
Domestic	0.45	0.49	94.	50.
Transportation	13.	14.	13.	7.0
Total	93.	--	190.	--

Table 7. ESTIMATED EMISSION OF OXIDES OF SULFUR IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	130.	54.	130.	32.
Incineration	0.35	0.14	0.35	0.086
Industrial combustion	86.	35.	86.	21.
Industrial processes	23.	9.5	23.	5.6
Area sources				
Commercial	2.0	0.82	28.	6.9
Domestic	0.29	0.12	140.	34.
Transportation	1.4	0.58	1.4	0.34
Total	240.	--	410.	--

Table 8. ESTIMATED EMISSIONS OF CARBON MONOXIDE IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	0.021	0.006	0.021	0.006
Incineration	7.0	2.0	7.0	2.0
Industrial combustion	0.026	0.007	0.026	0.007
Industrial processes	a	a	a	a
Area sources				
Commercial	b	b	b	b
Domestic	a	a	b	b
Transportation	350.	98.	350.	98.
Total	360.	--	360.	--

[a]Not applicable.
[b]Not estimated.

the daily emission of 360 tons is from transportation sources. Although the total amount emitted to the air is large, it is felt that carbon monoxide does not constitute an area wide problem in the Jacksonville area. Because the major source is the automobile, however, problems might occur among individuals working in the environment immediately adjacent to main thoroughfares.

Carbon Dioxide

Most investigators do not include carbon dioxide in their consideration of air pollution problems. Certain researchers, however, are concerned about the long range effect of this pollutant on man's environment. Plass[16], in 1939, stated that a relationship exists between the increase in carbon dioxide content of the atmosphere due to man's activities, and an increase in the annual average temperature of certain European cities. Kaplan[17], on the other hand, has presented evidence that the increase in carbon dioxide content could only account for 10 percent of this annual increase in average temperature.

What the long term effect of increasing carbon dioxide emissions to the atmosphere will be, only time will tell. Carbon dioxide in combination with water vapor, however, can cause the deterioration of building materials such as limestone and also cause the corrosion of magnesium.[18]

Estimated daily summer and winter emissions of carbon dioxide to the air over the Jacksonville area are 16,000 and 31,000 tons, respectively (Table 9). All these emissions result from combustion processes. This pollutant could be used as an index of over-all combustion activities in the Jacksonville area. Other investigators have used carbon dioxide in this manner.[19] Carbon dioxide concentrations over any city would be much higher than any other pollutant, and, therefore, easier to measure.

OTHER INORGANIC GASES

Hydrogen Sulfide

Table 10 shows the estimated emissions of hydrogen sulfide in the Jacksonville area. The summer and winter estimates are 5.1 and 7.7 tons per day, respectively. The water aeration plants in the city, which emit 0.15 tons of hydrogen sulfide per

Table 9. ESTIMATED EMISSIONS OF CARBON DIOXIDE IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	5700.	35.	5700.	18.
Incineration	700.	4.4	700.	2.2
Industrial combustion	8200.	51.	8200.	26.
Industrial processes	a	a	a	a
Area sources				
Commercial	190.	1.2	290.	0.93
Domestic	3.0	0.019	15,000.	48.
Transportation	1300.	8.1	1300.	4.2
Total	16,000.		31,000	--

[a]Not applicable.

Table 10. ESTIMATED EMISSIONS OF HYDROGEN SULFIDE IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	1.9	37.	1.9	25.
Water aeration	0.15	2.9	0.15	2.0
Industrial combustio	1.0	20.	1.0	13.
Industrial processes	2.0	39.	2.0	26.
Area sources				
Commercial	0.06	1.2	0.10	1.3
Domestic	a	a	2.5	33.
Transportation	a	a	a	a
Total	5.1	--	7.7	--

[a]not estimated.

day, are a particularly troublesome cause of nuisance complaints, since the pollutant is emitted near ground level.

Sulfide-type damage to paints containing lead pigments and/or mercury-base fungicides has occurred in the Jacksonville area. It can be presumed that emissions of hydrogen sulfide may cause an air pollution problem in this community.

Hydrogen Fluoride

It is estimated, based largely on data provided by industrial representatives in the area, that an average of 0.06 tons per day of fluorides are emitted annually from industrial processes. Because of variations in production rates, however, emissions on any given day may be considerably more or less than the average. In the space heating season, an additional 0.01 tons of fluorides are emitted per day from domestic sources (Table 11). It is doubtful whether the fluoride contribution of the area-wide domestic source constitutes an air pollution problem. This inventory indicates that the industrial process emission of 0.06 tons per day from local sources might be a problem in the vicinity of certain industrial operations. This should be the subject of further study.

Table 11. ESTIMATED EMISSIONS OF HYDROGEN FLUORIDE IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Industrial processes	0.06	100.	0.06	86.
Area sources				
Domestic	--	--	0.01	14.
Total	0.06	--	0.07	--

Table 12. ESTIMATED EMISSIONS OF PARTICULATES IN THE JACKSONVILLE URBAN AREA

Sources	Summer		Winter	
	Estimated emissions, tons/day	% of total estimated emissions	Estimated emissions, tons/day	% of total estimated emissions
Local sources				
Power generation	10.	34.	10.	21.
Incineration	3.9	13.	3.9	8.2
Industrial combustion	14.	47.	14.	29.
Industrial processes	0.12	0.40	0.12	0.25
Area sources				
Commercial	0.10	0.34	0.15	0.31
Domestic	0.13	0.42	18.	38.
Transportation	1.6	5.3	1.6	3.4
Total	30.	--	48.	--

PARTICULATES

Estimated daily emissions of particulates in the Jacksonville area are shown in Table 12. Thirty tons are discharged daily during the summer months; this increases to 48 tons per day during the winter season, the increase being due to domestic heating activities.

It is improbable that these amounts of particulates discharged to the atmosphere would constitute a potential areawide air pollution problem. A potential nuisance problem might exist, however, in areas close to the local sources listed in Table 12.

INDICATIONS

This inventory indicates that the following pollutants constitute a real or potential problem in the Jacksonville area and as such should be evaluated in greater detail.

1. Hydrocarbons
2. Oxides of nitrogen
3. Oxides of sulfur
4. Hydrogen sulfide
5. Fluorides
6. Particulates

METEOROLOGICAL STUDIES

Jacksonville, Florida, in general is quite well located topographically for the dispersion of waste material emitted to the atmosphere. There are no hills to act as barriers to air flow over the terrain, or valleys to hold and concentrate pollutants in the air. Unfortunately, there are other conditions in the area conducive to concentrating contaminants released to the atmosphere.

In the southeastern portion of the United States, it is not unusual for large high pressure systems in the atmosphere to move very slowly. This causes stable conditions near the earth's surface and, frequently, at some point above the ground because of subsidence in the air mass and radiational cooling during the hours of darkness. Surface-based inversions in the Jacksonville area occur throughout the year and are generally accompanied by light surface winds. In addition, the industrial area and the principal business district of the city lie along the west bank of the St. John's River, which flows from south to north for approximately 4 miles. At both ends of this 4-mile stretch, the river makes a 90-degree turn. The river and city buildings have a direct influence on wind direction and speed in this area.

The dispersion of gaseous and fine-particulate wastes emitted to the atmosphere is associated with the height at which they are released, wind speed and direction, and the stability condition of the atmosphere, among other things.

Good dispersion of any contaminant is favored by its release at high levels above ground, high wind speeds (with associated turbulence), and unstable conditions in the lower levels of the atmosphere. Even under such conditions, strong winds may bring some contaminants to ground level in relatively high concentrations. This would result from looping of the stack plume associated with turbulent air currents (gusty winds) developed in the atmosphere because of surface obstructions and/or changes in direction and speed of the wind.

Poor dispersion of pollutants emitted to the atmosphere occurs when stable air layers (inversions) form either at the ground or within a few hundred feet above the surface. The development of such stable conditions in the lower levels prevents vertical mixing of pollutants and holds them within or below these inversions. Low wind speeds accompany such stable conditions. In the Jacksonville area, conditions for poor disper-

sion of contaminants frequently exist during all months of the year.

The following analyses of meteorological conditions in the area establish the strong possibility that air pollution problems will intensify unless some preventive action is taken.

PAST STUDIES

Climatic conditions for this area are summarized in the "Report on Florida's Air Resources."[20] This report includes the following information:

1. Long-term means of wind direction and speed.
2. Annual percentage frequencies of wind direction.
3. Sea and land breezes.
4. Percent frequency of inversions with base at 500 feet or below.
5. Frequency of atmospheric stagnation conducive to air pollution.
6. Frequency of thunderstorms.
7. Long-term means of annual number of days with fog and cloudiness.
8. Frequency of occurrence of smoke.

This information provides a background for consideration of the general problem of air pollution. However, the micrometeorological aspects of the weather experienced in the Jacksonville area vary considerably from the long-term means.

METEOROLOGICAL CONDITIONS DURING THE PILOT STUDY

The pilot study of the air pollution conditions existing in Jacksonville and its adjoining industrial area raised quite a problem concerning actual meteorological conditions for dispersion of pollutants. Meteorological data were available from the U. S. Weather Bureau (USWB) at Imeson Airport approximately 5.5 miles north of the sampling area and from the U. S. Naval Air Station located approximately 7.5 miles south of the survey area. Data from these stations were not too helpful, however, when considering dispersion of pollutants in the study area.

Wind Speed and Direction

Table 13 compares the variances in wind speed and direction as determined from official records at the two weather stations for the sampling period 0700, September 5, through 0900, September 13, 1961. During the 195 hours of sampling, the USWB had 12 hours and the U. S. Naval Air Station 34 hours of winds from calm to 3 mph. In general, winds during the entire period were lighter at the Naval Air Station than at Imeson Airport. When wind speeds were light at either or both stations,

Table 13. COMPARISON OF OBSERVATIONS AT USWB, IMESON AIRPORT, AND AT THE U. S. NAVAL STATION

Date (Sept)	USWB, Imeson Airport		U.S. Naval Air Station		No. of hours wind directions varied 45 degrees or more between stations
	Avg hourly wind speed, mph	No. of hours wind calm to 7 mph	Avg hourly wind speed, mph	No. of hours wind calm to 7 mph	
5	10.8	7	7.2	9	6
6	10.0	3	6.6	12	7
7	11.7	6	7.9	12	8
8	11.5	9	8.5	13	9
9	12.3	7	7.9	13	7
10	9.5	10	6.2	19	7
11	9.1	7	4.9	18	8
12	10.1	14	6.2	16	10
13	3.0	4	0.6	8	7

the indicated wind direction could vary by 180 degrees. There were 69 hours when wind directions differed by 45 degrees or more. When wind speeds reached 10 mph or greater at both stations, the wind directions recorded were the same or, at most, differed by one compass point (22 1/2 degrees).

The wind instrument at the Imeson Airport station of the USWB is located about 52 feet above ground and at the U. S. Naval Air Station about 30 feet. Both stations take their hourly reading close to the end of the hour when direction and velocity are determined from approximately a one- to two-minute observation. The observations are comparable, and the difference in height may account for part of the higher velocity at the USWB station. In the study of dispersion of pollution in an area, it is this wind speed at the lower levels, however, that is most important. Because the data in Table 13 varys it is questionable whether the wind data recorded at the above two stations are indicative of air flow over the industrial area studied.

The U. S. Weather Bureau office at Imeson Airport is the official weather station for this area; therefore, the climatological records for the period October 1960 through September 1961 were used in this analysis. As expected, there are some variances from the long-term means published in "Florida's Air Resources."[20] Table 14 summarizes hourly wind velocities that occurred over the 12-month period. Winds were calm to 7 mph for 38 percent of the hours during the year. Wind speeds of 7 mph or less are conducive to accumulation of emitted pollutants, if a stable condition in the lower levels of the atmosphere exists.

Table 14. HOURLY WIND VELOCITY OBSERVATIONS - USWB, IMESON AIRPORT

Period	Number of hourly observations at various wind velocities					
	Calms	1-3 mph	4-7 mph	8-12 mph	>12 mph	Total hours 0-7 mph
October 1960	25	93	295	235	96	413
November 1960	11	81	265	268	95	357
December 1960	26	134	305	166	113	465
January 1961	5	48	203	274	214	256
February 1961	3	27	119	271	252	149
March 1961	0	48	142	282	272	190
April 1961	1	33	165	247	273	199
May 1961	4	59	163	264	254	226
June 1961	3	30	223	271	193	256
July 1961	3	49	207	340	145	259
August 1961	1	49	234	257	203	284
September 1961	1	58	197	229	225	256
Total for year	83	709	2,518	3,104	2,335	3,310

Fog, Smoke, and Haze Observations

Table 15 shows the number of days and hours during which fog, smoke, and haze occurred. The number of hours of fog, fog with smoke, and smoke or haze conditions over the Jacksonville area indicate that long periods of stable atmospheric conditions occur.

Cloud Ceiling and Visibility

Other indicators of stable air conditions are cloud ceiling and visibility. Cloud ceiling is the elevation above ground of the base of clouds at times when the degree of cloud cover is more than 50 percent. These data are also associated with the fog conditions tabulated in Table 15. Ceiling and visibility data were broken down into three categories as follows:

1. When cloud ceiling and visibility are equal to , or less than, 200 feet and 1/8 mile, respectively.

2. When cloud ceiling and visibility are equal to, or less than, 800 feet and 2 miles, respectively.

3. When cloud ceiling and visibility are equal to, or less than, 1500 feet and 3 miles, respectively.

Table 16 summarizes these data.

From Tables 14, 15, and 16, probable periods of stable conditions in the atmosphere in the Jacksonville area can be approximated. The U. S. Weather Bureau data from Imeson Airport

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Table 15. FOG, SMOKE, AND HAZE OBSERVATIONS - USWB, IMESON AIRPORT

Month	Number of days	Number of hours		
		Fog	Fog with smoke	Smoke or haze
October 1960	a	64	26	51
November 1960	a	139	69	156
December 1960	a	40	18	108
January 1961	17	85	38	81
February 1961	21	86	82	157
March 1961	14	33	24	41
April 1961	7	13	6	12
May 1961	23	26	12	62
June 1961	14	21	8	29
July 1961	8	20	10	18
August 1961	14	34	21	41
September 1961	14	41	24	60
Total for year		603	418	814

[a]Not available.

indicate that during approximately 38 percent of the time stable conditions exist that would result in accumulation of pollution in the lower levels of the atmosphere.

Inversion Frequency

Climatological records from the National Weather Records Center, Asheville, North Carolina, give information as to the percent frequency of inversions to be expected at Jacksonville (Table 17). The data are not entirely suitable, however, for determining probable periods favorable for accumulation of pollution; they were obtained from radio soundings taken at fixed times during the day--at either 0700 or 0800 and at 1900 or 2000. During the year, the hour of sunrise and sunset varies considerably between winter and summer. The surface inversion, with which air pollution at ground level is closely associated, generally breaks down shortly after sunrise and regenerates sometime during the evening between sunset and midnight when conditions are favorable. Because of the time of the soundings, an erroneous opinion might be developed as to what one might expect regarding the actual percent frequency of inversions that developed during the year. This factor is quite noticeable in

comparing the percent frequency of inversions indicated at 0700 and 0800 and also the evening soundings taken at 1900 and 2000 EST.

Table 16. HOURLY OBSERVATIONS OF CLOUD CEILING AND VISIBILITY - USWB, IMESON AIRPORT

Period	Number of hourly observations of cloud ceiling and visibility equal to or less than indicated range		
	200 ft and 1/8 mi	800 ft and 2 mi	1500 ft and 3 mi
October 1960	1	18	25
November 1960	13	45	109
December 1960	7	14	61
January 1961	10	80	105
February 1961	11	71	121
March 1961	2	17	33
April 1961	--	16	30
May 1961	3	19	32
June 1961	1	19	46
July 1961	3	13	25
August 1961	1	23	45
September 1961	4	24	43
Total for year	56	359	675

Table 17. PERCENT FREQUENCY OF INVERSIONS WITH BASE AT 500 FEET OR BELOW AT USWB STATION AT IMESON AIRPORT[a]

Season	% of observations indicating inversions at stated hour, EST			
	June 1955 to May 1957		June 1957 to May 1959	
	0800	2000	0700	1900
Winter	27	69	59	44
Spring	4	53	61	10
Summer	1	38	56	11
Fall	12	51	76	37

[a]Data are from National Weather Records Center, Ashville, N. C.

The time at which stability develops was determined during the period September 5-13, 1961, when a resistance dynalog temperature-differential recording instrument was being operated. The lower element was 7 feet above ground and the upper element 140 feet. The 140-foot height was low enough to give excellent microstability data, yet was higher than all pollutant sources except the two 250-foot stacks at the pulp mill in the East Jacksonville industrial area. Stability in the lower 140 feet of the atmosphere developed each night beginning between 2000 and 2300 and dissipated the following morning between 0700 and 0830 (Table 18).

Table 18. TEMPERATURE PROFILE OBSERVATIONS - JACKSONVILLE, FLORIDA, SEPT. 5-13, 1961

Date (Sept)	Stable conditions					Unstable conditions	
				Maximum strength of inversions		Maximum strength of unstable conditions	
	Time[a] inversion developed	Time[a] inversion dissipated	Duration, hours	Time[a]	Lapse rate to 140 ft, °F	Time[a]	Lapse rate to 140 ft, °F
5- 6	2100	0730	10.5	-	-	1400	-2.7
6- 7	2100	0700	10	0300	+2.2	1500	-2.2
7- 8	2300	0730	8.5	0300	+1.9	1300	-2.3
8- 9	2200	0700	10	0500	+1.5	1300	-2.1
9-10	2000	0830	12.5	0600	+2.2	1500	-2.1
10-11	2230	0800	9.5	0300	+1.2	1400	-2.3
11-12	2000	0800	12	0100	+2.2	1500	-1.5
12-13	2100	0700	10	0100	+1.9	2200	-2.3

[a]EST.

With reference to stability of the atmosphere, the term "lapse rate" is used frequently. Lapse rate is defined as the rate of change of temperature upward through the atmosphere. If it is negative (temperature decreases with altitude) the air can be in either a neutral or an unstable condition; if positive (temperature increases with altitude), the atmosphere is considered to be in a stable condition conducive to accumulation of pollutants in the air.

Table 18 gives the time of development and dissipation of ground inversions, the time and maximum inversion lapse rate developed, and the time and maximum lapse rate indicated during unstable conditions. The data indicate a ground inversion occurs almost nightly. These inversions normally occur when winds are light and the sky is partly cloudy to clear.

Precipitation

Precipitation occurred on an average of 12 days a month from October 1960 to September 1961. Precipitation generally reduces the gaseous and particulate contaminants in the air, and washes pollutants off the surface of vegetation. The importance of precipitation as a factor influencing pollution levels is considered negligible, however.

SUMMARY OF METEOROLOGICAL STUDIES

The results of the preceding observations are summarized as follows:

1. Jacksonville has weather conditions throughout the year that are conducive to accumulation of pollutants emitted to the atmosphere.

2. If dispersion of pollutants from particular sources is to be studied, a wind speed and direction recorder located within the specific study area will be necessary. Also, an instrument to measure on a continuous basis or at frequent intervals the lapse rate in the lowest few hundred feet would be essential. Meteorological data from the USWB station at Imeson Airport and from the Naval Air Station would be inadequate for such detailed studies.

PILOT AIR QUALITY STUDY

In addition to providing field training for local personnel in air pollution technology, the main objectives of this pilot study were:

1. To develop a preliminary opinion as to whether the city of Jacksonville has a generalized air pollution problem.

2. To determine whether certain pollutants were present in the atmosphere in concentrations capable of producing the plant damage that had been experienced in the Jacksonville-Duval County area.

Two separate investigations were designed to meet these objectives: the "urban investigation" to determine whether certain pollutants were present in concentrations indicative of a generalized air pollution problem, and the "industrial area investigation" to meet the second objective. These two investigations are discussed separately in this report, even though certain phases of both were carried out concurrently by the same personnel.

The engineers and chemists assigned to this study by the Public Health Service, State Board of Health, and Jacksonville Health Department comprised the sampling team. This group planned and supervised the study, calibrated and maintained sampling equipment, standardized reagents, performed the detailed laboratory analyses, and processed the data. Sample collection, transportation of samples to the laboratory, routine laboratory analyses, and washing of laboratory glassware was handled by virtually the entire staff of sanitary inspectors of the City Health Department. During the second phase of the study, laboratory analyses, excepting those for fluorides, were performed in the City Health Department's stream pollution laboratory by the City Sanitary Engineer and several of the sanitary inspectors.

THE URBAN INVESTIGATION

The urban investigation, patterned after previous studies in Phoenix, Arizona,[21] and Washington, D. C.,[22] was conducted at a downtown site from August 3 to 10, 1961. The site selected was the Hemming Park bandstand located near the center of the city business district (Figure 3). The State Board of Health's stream pollution laboratory trailer was located in Hemming Park and served as the survey headquarters and laboratory during the first phase of the survey. Table 19 summarizes the pollutants sampled, the sampling and analytical methods

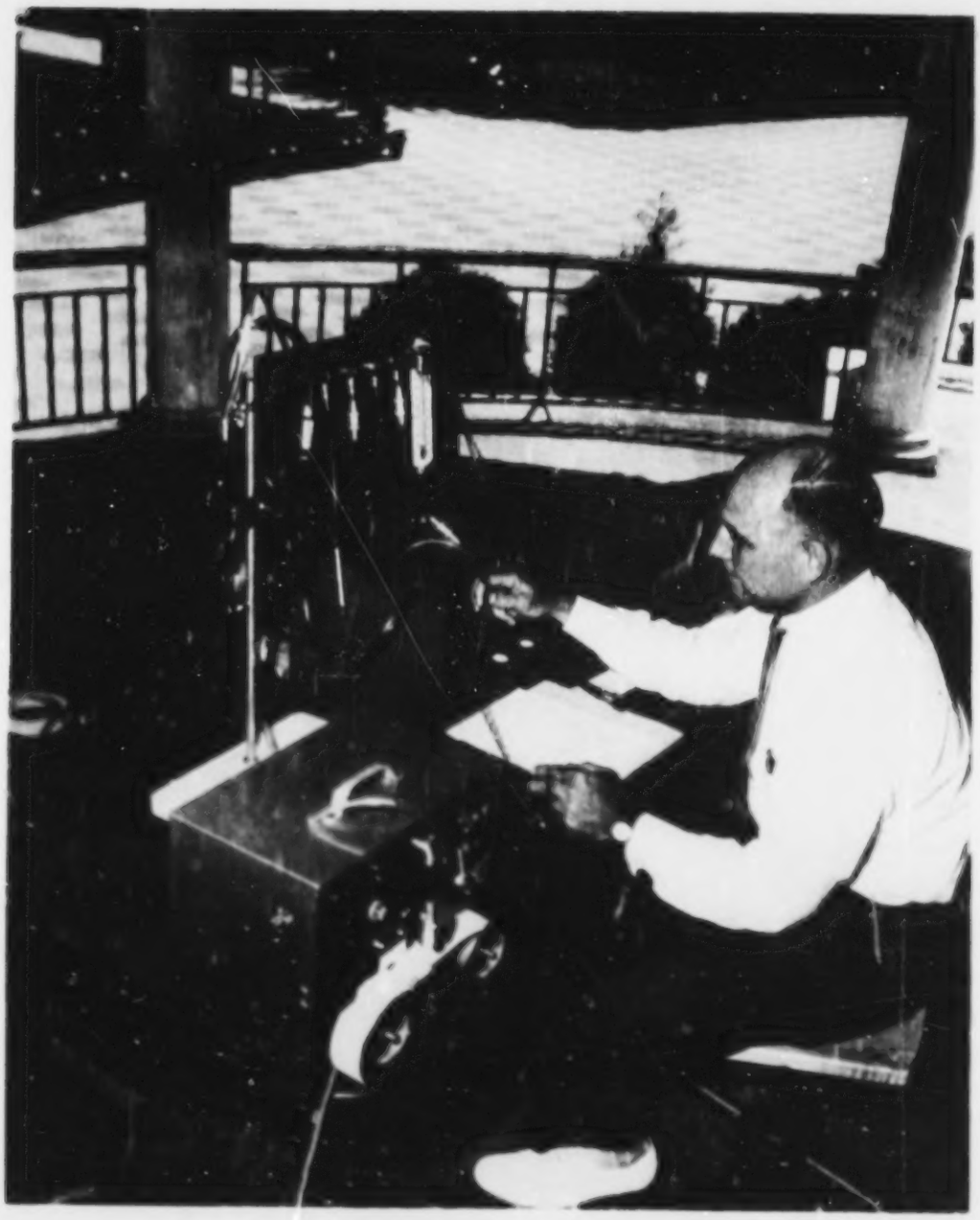

Figure 3. Thomas Ard, Sanitary Engineer, Jacksonville City Health Department, obtains sample of atmospheric oxidants at the Hemming Park site.

used, and the most common sources and effects of each pollutant. The sampling period and frequency for each pollutant measured at the Hemming Park site are listed in Table 20. Because the morning concentration of pollutants after the overnight buildup and the photochemical reactions of mid-day were of chief concern in the urban study, the Hemming Park samples were collected every two hours from 0530 through 1430. On Sunday, August 7, and Monday, August 8, sampling was

Table 19. SUMMARY OF POLLUTANTS STUDIED AT THE HEMMING PARK SITE, JACKSONVILLE, FLORIDA

Pollutant	Source	Effect	Method of sampling	Method of analysis
1. Sulfur dioxide (SO_2)	Combustion of fuels containing sulfur; industrial processes	Vegetation damage; possible health effects; corrosion	Midget impinger w/sodium tetrachloromercurate	West & Gaeke[23]
2. Oxidant (as H_2O_2)	Photochemical reactions	Eye irritation; vegetation damage; visibility reduction; other possible health effects	Midget impinger w/phenolphthalein	Spectrophotometrically[24]
3. Nitrogen dioxide (NO_2)	Industrial processes; high temperature combustion processes, including automobiles	Human irritation; possible health effects	Smog bubbler	Jacobs & Hochheiser[25]
4. Carbon monoxide	Incomplete combustion, predominantly auto exhaust	Possible health effects	NBS detector tubes	Color comparison
5. Particulate matter	Combustion processes; industrial processes; wind erosion	Soiling; visibility reduction; corrosion; possible vegetation damage	a. Hi-volume sampler b. AISI tape sampler	a. Weight b. Spot analyzer (light transmission through filter)

Table 20. SAMPLING PERIOD AND FREQUENCY - HEMMING PARK

Pollutant	Length and frequency of sampling
1. Sulfur dioxide	One 20-minute sample every 2 hours
2. Nitrogen dioxide	One 40-minute sample every 2 hours
3. Carbon monoxide	One sample every 2 hours (sampled until a given color developed)
4. Oxidant	One 10-minute sample every 2 hours
5. Particulate	a. Gross - 24-hour samples, continuously b. Soiling - 2-hour samples, continuously

continued through the night to determine the diurnal variation of pollutant concentrations.

From August 3 to 10, 261 analyses were made on samples of gaseous pollutants collected at the Hemming Park Station. Concentrations of oxidants, sulfur dioxide, nitrogen dioxide and carbon monoxide were determined (Table 21). Concentrations of all gases, except carbon monoxide, were initially determined as micrograms of contaminant per cubic meter of air sampled. The concentrations in parts per million by volume (ppm) were calculated from these values. For purposes of this report, concentrations mentioned in the discussion of results will be stated as parts per million by volume for ease in comparison with other studies.

Table 21. INDICATED CONCENTRATIONS OF SELECTED GASEOUS POLLUTANTS - HEMMING PARK, JACKSONVILLE, FLORIDA

Date	Starting time	Oxidants (as H_2O_2)		Sulfur Dioxide (SO_2)		Nitrogen Dioxide (NO_2)		Carbon Monoxide (CO)
		$\mu g/m^3$	ppm[a]	$\mu g/m^3$	ppm[a]	$\mu g/m^3$	ppm[a]	ppm[b]
8/3/61	0535	41	0.029	0[c]	0	-	-	2.3
	0730	0	0	2.1	0.001	-	-	2.3
	0830	66	0.047	34.	0.013	-	-	3.1
	0930	176	0.126	29.	0.011	-	-	5.0
	1030	98	0.070	2.4	0.001	-	-	4.2
	1130	127	0.091	2.4	0.001	-	-	8.3
	1230	113	0.081	0	0	-	-	3.1
	1330	176	0.126	9.6	0.004	-	-	25.0
	1430	144	0.104	0	0	-	-	8.3
	1530	133	0.096	0	0	-	-	8.3
	1630	144	0.104	6.0	0.002	-	-	4.2
8/4/61	0530	82	0.059	7.3	0.003	-	-	2.8
	0630	123	0.088	0	0	-	-	1.9
	0730	0	0	0	0	-	-	8.3
	0830	35	0.025	16.	0.006	-	-	1.4
	0930	125	0.090	6.0	0.002	-	-	1.1
	1030	-	-	17.	0.006	-	-	1.8
	1130	113	0.081	0	0	16.	0.008	2.5
	1230	32	0.059	0	0	21.	0.011	1.9
	1330	139	0.100	0	0	16.	0.008	1.6
	1430	105	0.076	2.4	0.001	21.	0.011	2.1
	1530	92	0.066	2.4	0.001	21.	0.011	3.6
8/5/61	0530	107	0.077	11.	0.004	94.	0.050	0.3
	0630	78	0.056	4.8	0.002	13.	0.007	-
	0730	78	0.056	0	0	23.	0.012	1.9
	0930	59	0.042	12.	0.005	16.	0.008	1.0
	1130	62	0.044	0	0	21.	0.011	1.0
	1330	65	0.047	0	0	19.	0.010	0.7
	1530	65	0.047	0	0	0	0	1.2
8/6/61	0530	133	0.096	1.2	0.001	0	0	0.3
	0730	90	0.065	0	0	11.	0.008	1.2
	0930	0	0	14.	0.005	27.	0.014	1.2
	1130	0	0	14.	0.005	21.	0.011	0.6
	1330	124	0.089	2.4	0.001	37.	0.020	0.7
	1530	0	0	2.4	0.001	21.	0.011	0.4
	1730	11	0.008	-	-	27.	0.014	0.4
	1930	40	0.029	24.	0.009	32.	0.017	0.7
	2130	47	0.034	240.	0.092	37.	0.020	3.3
	2330	-	-	130.	0.049	53.	0.028	0.5
8/7/61	0130	22	0.016	72.	0.028	27.	0.014	0.6
	0330	63	0.045	0	0	27.	0.014	0.4
	0530	40	0.029	84.	0.032	43.	0.023	0.4
	0730	56	0.040	50.	0.019	69.	0.037	1.1
	0930	124	0.089	18.	0.007	21.	0.011	1.1
	1130	146	0.105	19.	0.007	27.	0.014	2.5
	1330	225	0.162	6.0	0.002	11.	0.006	1.5
	1530	129	0.093	2.4	0.001	16.	0.008	1.4
	1730	79	0.057	17.	0.006	5.3	0.003	8.3
	1930	0	0	26.	0.010	24.	0.012	1.3
	2130	22	0.016	460.	0.174	5.3	0.003	1.0
	2330	0	0	180.	0.069	27.	0.014	1.0
8/8/61	0130	0	0	17.	0.006	32.	0.017	-
	0330	0	0	24.	0.009	16.	0.008	-
	0530	0	0	12.	0.005	11.	0.008	0.9
	0730	73	0.052	340.	0.128	21.	0.011	2.4
	0930	32	0.023	91.	0.035	24.	0.012	1.5
	1130	68	0.049	6.0	0.002	9.7	0.005	1.2
	1330	90	0.065	0	0	2.2	0.001	1.0
	1530	68	0.049	4.8	0.002	11.	0.006	0.8
8/9/61	0530	68	0.049	74.	0.028	11.	0.006	0.4
	0730	47	0.034	180.	0.069	21.	0.011	1.6
	0930	90	0.065	74.	0.028	0	0	1.3
	1130	135	0.097	55.	0.021	21.	0.011	3.1
	1330	52	0.037	3.6	0.001	21.	0.011	1.7
	1530	68	0.049	12.	0.005	32.	0.017	5.0
8/10/61	0530	0	0	31.	0.012	21.	0.011	0.4
	0730	0	0	53.	0.020	30.	0.016	1.3
	0930	88	0.063	230.	0.087	32.	0.017	1.4
	1130	68	0.049	26.	0.010	43.	0.023	5.0
	1330	0	0	6.0	0.002	37.	0.020	2.8
	1530	68	0.049	2.4	0.001	11.	0.006	1.8

[a] Calculated from $\mu g/m^3$, assuming pollutant analysed existed as a gas.

[b] Detector tubes used in sampling read directly in ppm.

[c] Concentration of 0 indicates that not enough pollutant was obtained to enable detection by analytical method used.

None of the gaseous sampling methods used were 100 percent efficient. Concentrations reported are in all cases less than the true concentration in the original sample. Any sample obtained over a period of time gives an average concentration for that time. Actual pollutant concentrations existing at a specific instant during the sampling period can be expected to be greater and less than those indicated by the sample. Therefore, in view of the fluctuating concentrations of the pollutants measured, and the expected efficiencies of the sampling equipment, concentrations reported for various pollutants are really "minimum" estimates of the concentrations occurring during the sampling period.

Sulfur Dioxide

Concentrations of sulfur dioxide in 70 samples are summarized in Table 22. Sulfur dioxide concentrations ranged from 0.0 to 0.174, with a mean and median of 0.015 and 0.004 ppm, respectively. An arithmetic probability plot of the data is presented in Figure 4. During this study 95 percent of the sulfur dioxide concentrations were less than 0.092 ppm. Concentrations reached maximum levels during the night-time and early morning hours (Table 21). Although the concentrations of sulfur dioxide observed were generally low, the maximum concentration (0.174 ppm) during this non-heating period can be interpreted as a warning that concentrations could exceed levels that are known to cause damage to susceptible plants,[33] especially during winter months when space heating is necessary.

Oxidants

Concentrations of oxidants in 70 samples are summarized in Table 22. Oxidant concentration ranged from 0.000 to 0.162 ppm (as hydrogen peroxide), with a mean and median concentration of 0.052 and 0.049, respectively; 95 percent of the observations were less than 0.126 ppm.

On 5 of the 8 days of this study period, the diurnal pattern of oxidant concentrations indicated a photochemical type reaction similar to those patterns observed in Los Angeles, California,[26] Washington, D. C.,[22] and Cincinnati, Ohio.[27]

Oxidant-Sulfur Dioxide Relationship

Because sunlight is associated with the formation of oxidants in the atmosphere, oxidant levels below 0.05 ppm would be expected during the predawn hours. On 2 of the days, however, samples obtained at 0530 hours indicated oxidant concentrations of 0.077 and 0.096 ppm. A plot of oxidant and sulfur dioxide concentration on 3 of the days (August 6, 7, and 8) is shown in Figure 5. During the daylight hours, particularly on Monday, August 7, the oxidant patterns indicate a photochemical type

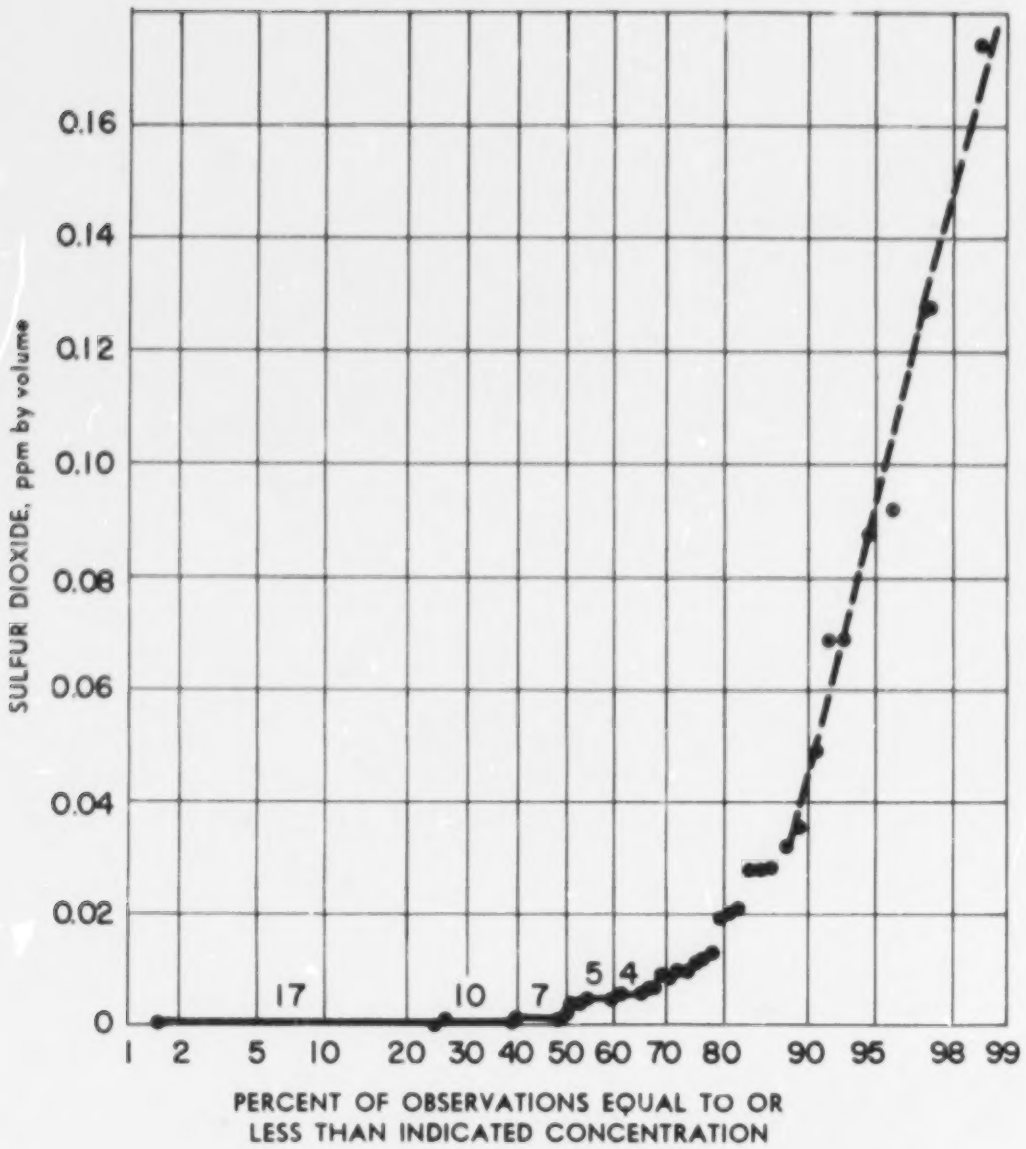

Figure 4. Sulfur dioxide concentrations observed in Hemming Park, Jacksonville, August 3-10, 1961.

reaction with high concentrations occurring when the sun is shining brightest. In general, sulfur dioxide concentration patterns during the daylight hours are the reverse of the oxidant levels. Since emission rates of sulfur dioxide during this study varied little with the time of day, one would expect maximum concentrations during the daytime when the ability of the atmosphere to diffuse pollutants would be at its maximum.

A relationship between oxidant levels and sulfur dioxide in the nighttime hours seems to exist. Non-daylight oxidant concentrations during this period were a maximum when sulfur dioxide concentrations were a minimum. No quantitative comparison can be made, however, until a determination is made

Table 22. SUMMARY OF INDICATED CONCENTRATIONS OF SPECIFIC GASEOUS POLLUTANTS IN SAMPLES OBTAINED AT HEMMING PARK, JACKSONVILLE, FLORIDA - AUGUST 3-10, 1961

Pollutant	No. of Samples	Concentration of gaseous pollutants[a]									
		Mean		Median		Maximum		Minimum		95% of observations equal to or less than indicated concentration	
		µg/m³	ppm	µg/m³	ppm	µg/m³	ppm	µg/m³	ppm	µg/m³	ppm
Sulfur dioxide (as SO_2)	70	40.	0.015	9.6	0.004	460.	0.174	0.	0.000	240.	0.092
Oxidants (as H_2O_2)	70	73.	0.052	68.	0.049	225.	0.162	0.	0.000	176.	0.126
Nitrogen dioxide (as NO_2)	54	26.	0.013	21.	0.011	94.	0.050	0.	0.000	53.	0.028
Carbon monoxide (as CO)	68	--	2.54	--	1.5	--	25.0	--	0.3	--	8.3

[a]Parts per million by volume calculated from µg/m³, assuming pollutant analyzed existed as a gas.

as to the quantitative interference of sulfur dioxide with this particular sampling method for oxidants. It is highly probable that non-daylight oxidant concentrations are higher than indicated by these data since the presence of sulfur dioxide in the air sampled causes measurements of oxidant to indicate lower values than the actual concentration of oxidant in the air sampled.

Nitrogen Dioxide

Nitrogen dioxide concentrations in 54 samples analyzed ranged from 0. to 0.05, the mean and median being 0.013 and 0.011 ppm, respectively (Figure 6); 95 percent of the observations were less than 0.028 ppm.

Carbon Monoxide

As summarized in Table 22, carbon monoxide concentrations in 68 samples analyzed at the Hemming Park site and range from 0.3 to 25.0 ppm, the mean and median being 2.54 and 1.50 ppm, respectively. Ninety-five percent of the observations were less than 8.3 ppm. The hourly data presented in Table 21 indicate that carbon monoxide peak concentrations occur at hours of the day when automobile traffic would be expected to be at a maximum in this part of Jacksonville. Quantitative comparison of carbon monoxide concentrations with those observed in other cities is not made as sampling sites are not comparable. The concentrations of this pollutant appear to be similar, however, to those reported in other cities in the United States.[7]

Airborne Particulates - Weight

During this period 24-hour hi-volume filtration samples for determination of total airborne particulate matter were obtained. Particulate loadings ranged from 50 to 105 micrograms per cubic meter (Figure 7). The maximum concentration occurred during the period starting at 1600 hours on Tuesday,

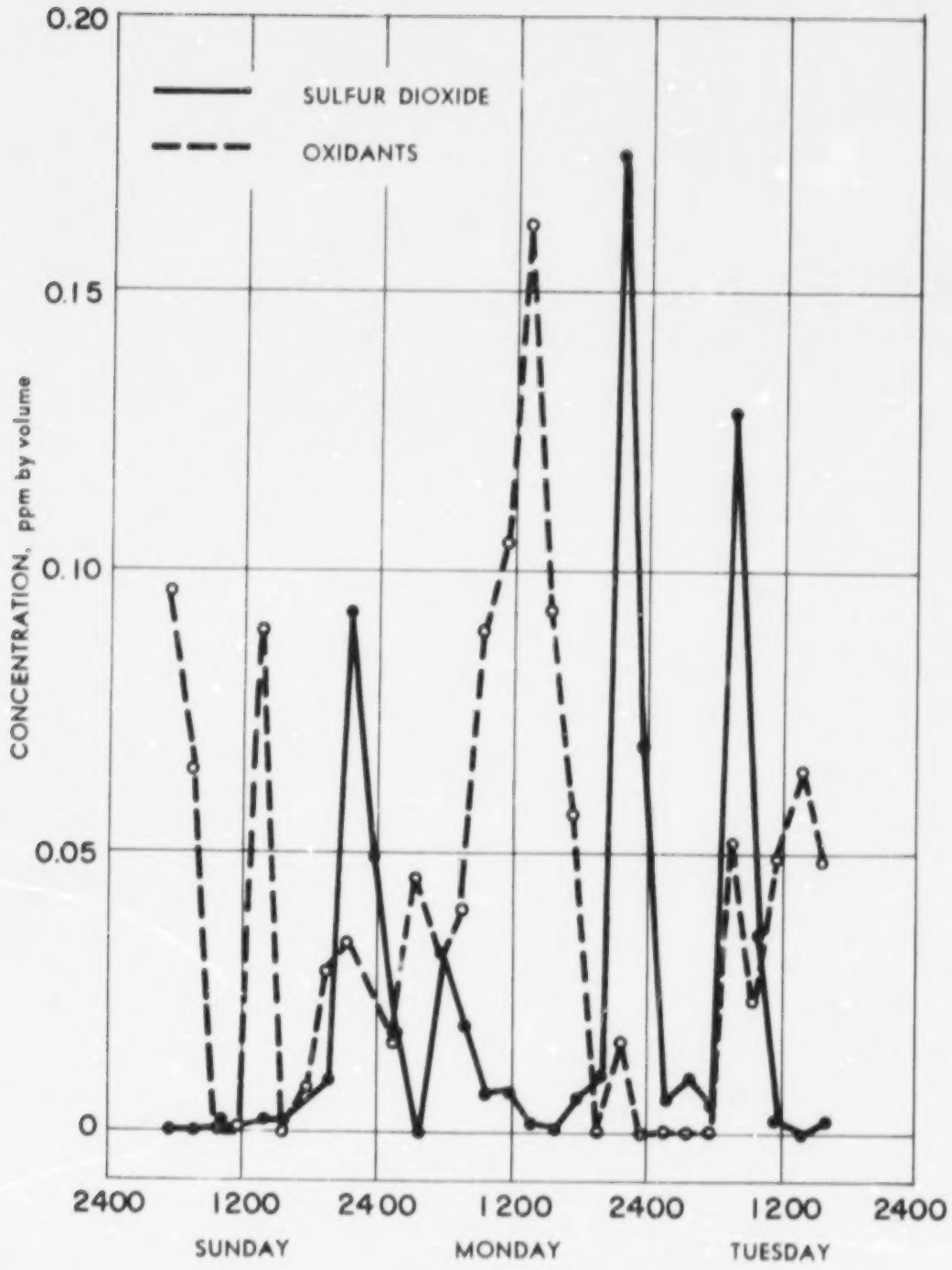

Figure 5. Oxidants and sulphur dioxide concentrations in Hemming Park, Jacksonville, August 6, 7, 8, 1961.

August 8, and ending at the same time on Wednesday. The data indicate that total particulate matter (by weight) was not a significant problem.

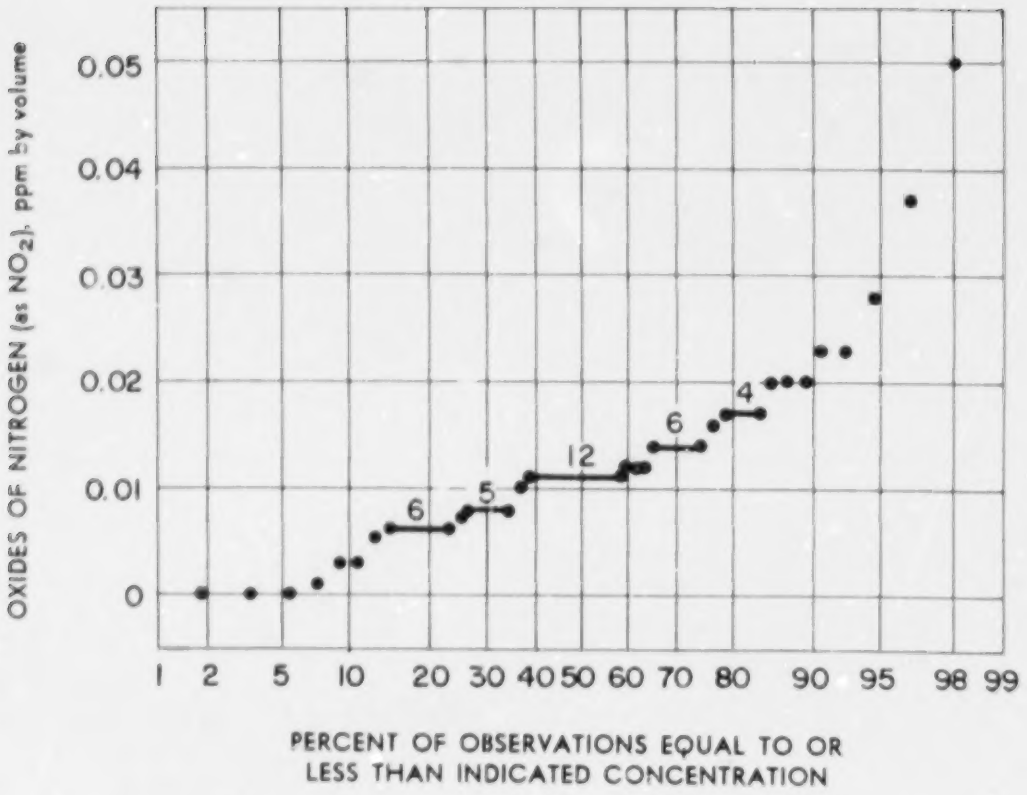

Figure 6. Distribution of indicated oxides of nitrogen concentrations in Hemming Park, Jacksonville, August 3-10, 1961.

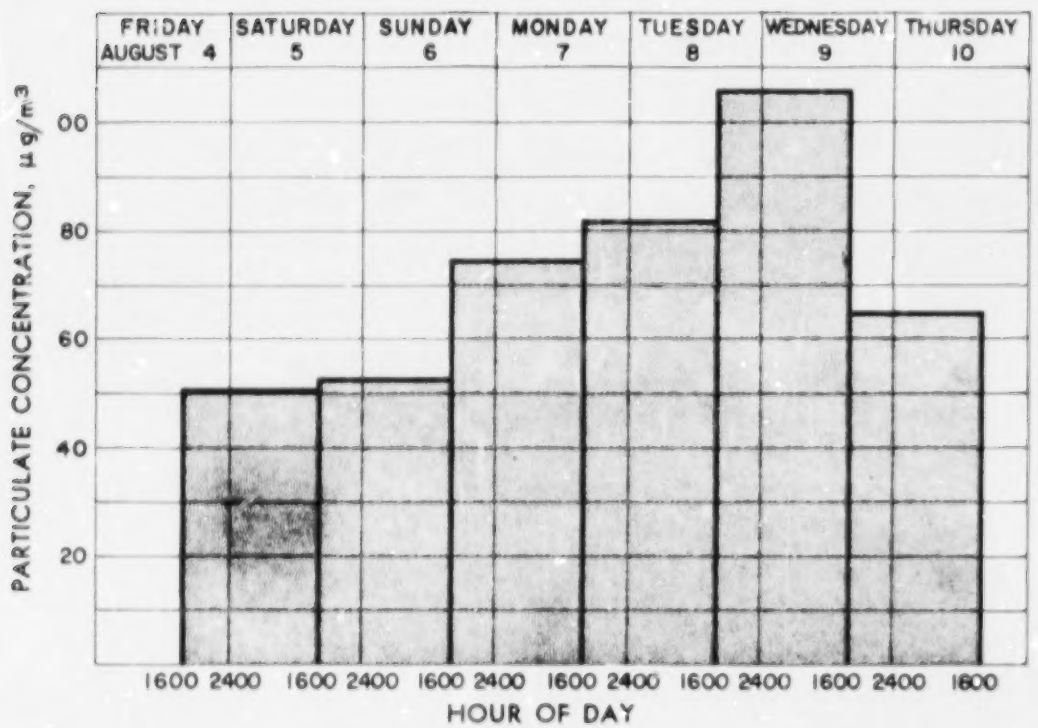

Figure 7. Airborne particulate concentration in Hemming Park, Jacksonville.

Soiling Index

The results of the 84 2-hour soiling index samples collected from August 4 - August 11, are shown in Figure 8. The soiling index is expressed in Cohs per 1000 linear feet. Values ranged from 0 to a maximum of 2.8 Cohs per 1000 Ft. The results in general indicate a considerable amount of soiling potential of the airborne particulates.

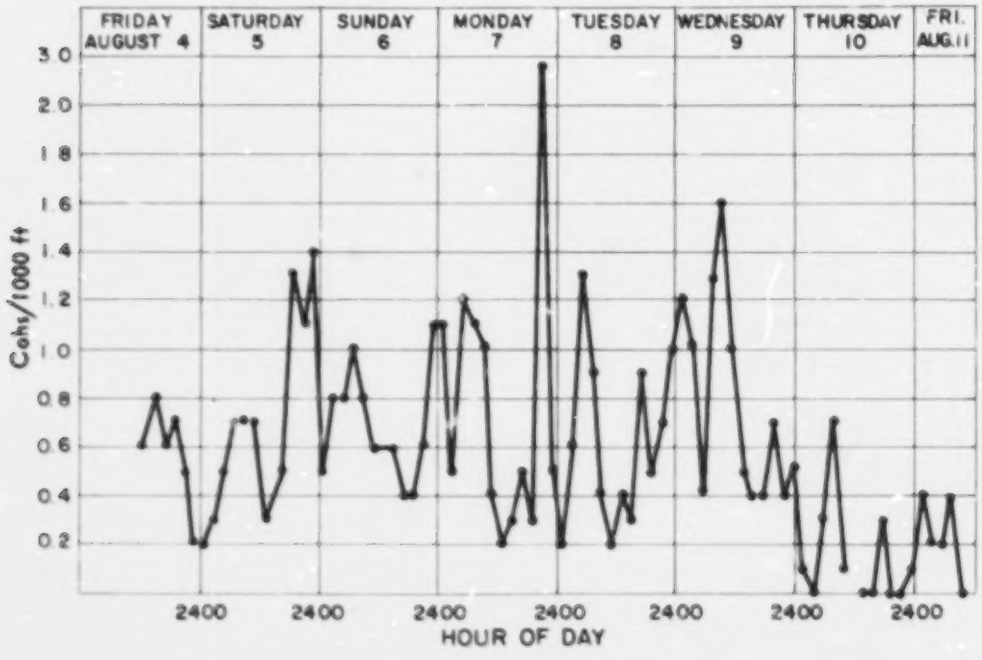

Figure 8. Soiling index in Hemming Park, Jacksonville, August 4-11, 1961.

Soiling Index Sulfur Dioxide Relationship

On August 6, 7, 8, and 9, the variations of concentration of these two pollutants with time were almost identical (Figure 9). This indicates that either meteorological conditions were such that the concentration of both pollutants varied in the same fashion or that both pollutants came from the same source, or both. Concentration patterns of the other gases did not exhibit the same relationship with soiling index that seems to exist with sulfur dioxide. Therefore, the sulfur dioxide and the fine particles causing the soiling were probably from the same source or sources.

Estimated and Measured Concentration

Some of the estimates of pollutant emissions presented earlier in this report have been used to calculate estimated concentrations of certain pollutants in the air over Jacksonville for three meteorological conditions. The methodology used was similar to that of other investigators.[7,28,29] These

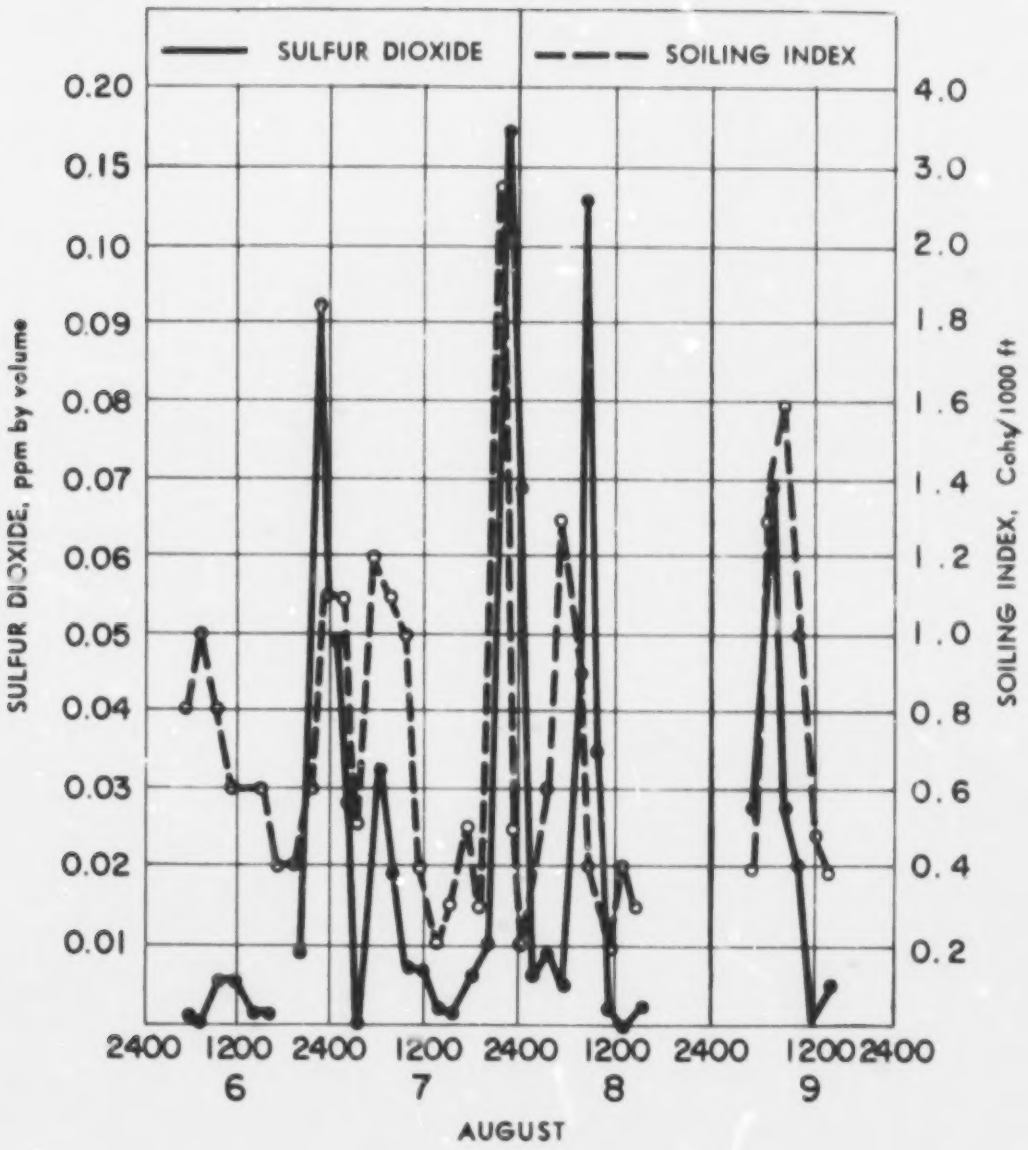

Figure 9. Patterns of SO_2 and soiling index, August 6-9, 1961, Hemming Park, Jacksonville.

estimates are presented in Table 23. The calculated estimates of pollutant concentrations are in the same general range as concentrations measured during the urban investigation. Estimates of atmospheric concentrations based on the emission inventory, in this case, can be used to determine the minimum air volume to be sampled in order to insure collection of enough pollutant for detection by available analytical methods.[29]

THE INDUSTRIAL AREA INVESTIGATION

Investigations of the extensive plant damage that occurred in the spring of 1961 implicated airborne fluoride and oxides of sulfur as possible causes.[5, 6] The area involved centered around the industrial zone bordering the St. John's River.

Table 23. ESTIMATED AND MEASURED CONCENTRATIONS OF SELECTED POLLUTANTS IN THE AIR OVER JACKSONVILLE, FLORIDA

Meteorological conditions for dispersion of pollutants	Estimated and measured concentrations		
	SO_2, $\mu g/m^3$	NO_2, $\mu g/m^3$	Particulates, $\mu g/m^3$
	Estimated		
500-ft mixing height 3-mph wind	545	211	68
1,000-ft mixing height 5-mph wind	174	67	22
2,000-ft mixing height 8-mph wind	56	21	6.9
	Measured		
Mean	40	26	71
Range	0. - 460	0. - 94	50 - 105

Therefore, the industrial area investigation was conducted in this area to determine whether or not the suspected pollutants were present in concentrations sufficient to cause damage to vegetation. The investigation was divided into two parts: Phase I from August 4 to 12, and Phase II from September 5 to 13, 1961.

Six sampling sites were selected (Figure 10). Station A was in the approximate geographic center of the area wherein vegetation damage had occurred. Stations B, C, D, and E were located roughly 0.75 miles north, south, east, and west of Station A. Station F was located between the two kraft pulp mills.

Because vegetation damage was a major motivating force in the industrial area study, all samples were collected at a height of 36 inches above ground in order to measure the pollutants at the level where much of the observed vegetation damage had occurred. Special tables were constructed by the City Health Department to house the sampling equipment and meet this criterion (Figure 11). Other criteria used in selecting the industrial area sampling sites were:

1. No site was selected at which a major air flow obstruction projected higher than 30 degrees above the horizon.

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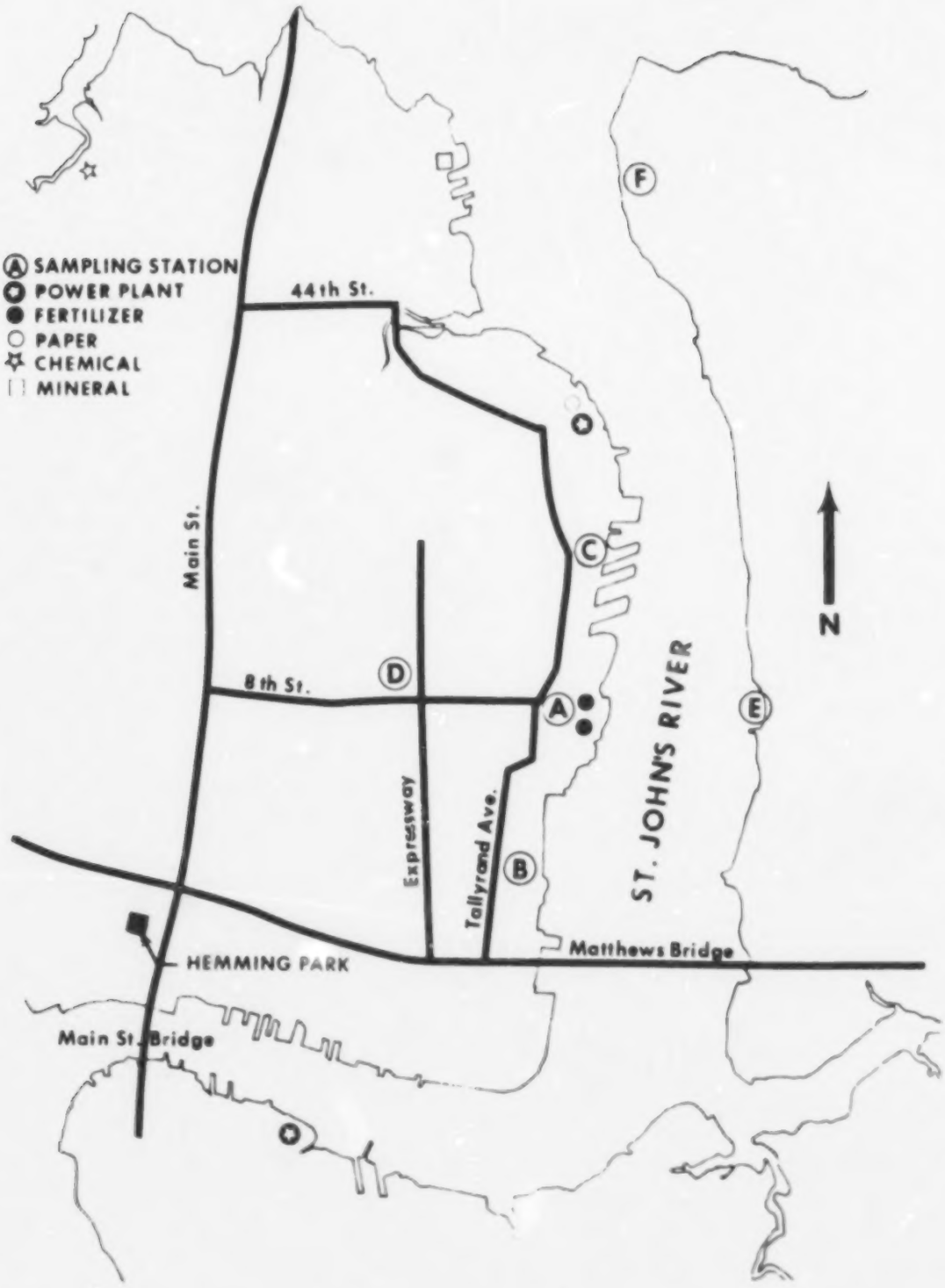

Figure 10. Location of major industries and sampling stations.

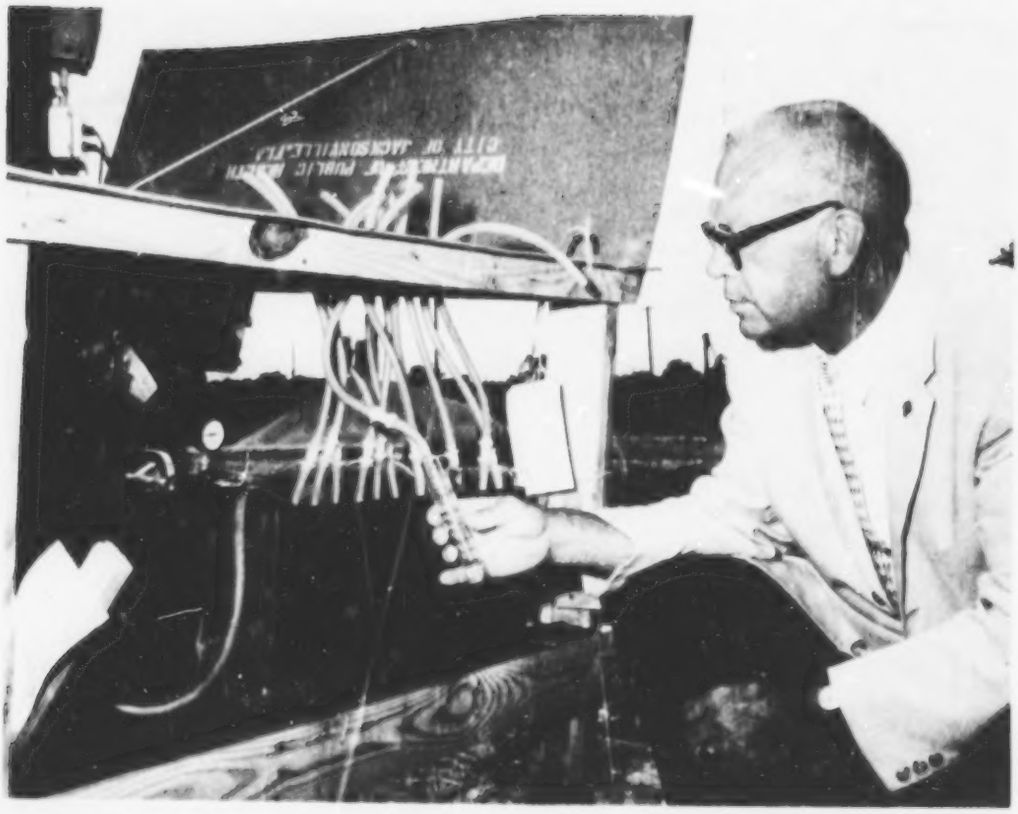

Figure 11. David B. Lee, Director, Bureau of Sanitary Engineering, Florida State Board of Health, inspects sampling equipment at Site A.

2. Electric power had to be available to operate sampling equipment. (The Jacksonville City Electric Department ran special power lines into four stations to satisfy this criterion.)

3. Every unmanned site had to be fenced to protect against pilfering. Only Station A was manned continuously.

The pollutants sampled, the sampling and anlytical methods used, and the most common sources of these pollutants are listed in Table 24.

The period of availability of the Public Health Service personnel coincided with the annual non-operating period of both the major fluoride sources. This permitted a background fluoride level to be established, but necessitated a second sampling period in the industrial area to measure fluorides during normal operation of the two major sources. The first phase of the industrial investigation was conducted concurrently with the downtown investigation.

Table 25 indicates the sampling frequency for each pollutant measured, and the sampling sites. Analyses for oxides of nitrogen, sulfur dioxide, and hydrogen sulfide were carried out by

Table 24. SUMMARY OF POLLUTANTS STUDIED DURING THE INDUSTRIAL AREA INVESTIGATION, JACKSONVILLE, FLORIDA, AUGUST - SEPTEMBER, 1961

Pollutant	Source	Method of sampling	Method of analysis
1. Fluoride (as F^-)	Industrial processes	a. Greenberg-Smith impinger w/NaOH b. Sodium bicarbonate coated tube[31] c. Dustfall jar d. Rain sampler	a. Modified Willard and Winter distillation process[30] b. Modified Willard and Winter distillation process c. Modified Willard and Winter distillation process d. Modified Willard and Winter distillation process
2. Sulfur dioxide (SO_2)	Combustion of sulfur in fuels; industrial processes	Midget impinger w/sodium tetrachloromercurate	West & Gaeke[23]
3. Hydrogen sulfide (H_2S)	Industrial processes; aeration of well water supplies	AISI tape sampler w/lead acetate tape	Soot analyzer (light transmission through filter)
4. Nitrogen dioxide (NO_2)	Industrial processes; high temperature combustion processes, including automobiles	Smog bubbler	Jacobs & Hochheiser[25]

Table 25. SAMPLING FREQUENCY AND GEOGRAPHIC DISTRIBUTION

Pollutant	Length and frequency of sampling	Sites sampled[a]
1. Fluoride	8-hour samples, continuously	A, B, C, D, E
2. Sulfur dioxide	One 20-minute sample every 2 hours	A, B, C
3. Oxides of nitrogen	One 40-minute sample every 2 hours	A[b]
4. Hydrogen sulfide	2-hour samples, continuously	B, C, F
5. Dustfall[b]	One sample for the entire 8-day period	A, B, C, D, E
6. Rainout	One sample per day collected only during periods of precipitation	A

[a]Figure 10.
[b]Sampled only during second phase of industrial study.

personnel of the Jacksonville City Health Department and the Public Health Service. The fluoride analysis, which involves a distillation procedure, is most efficiently conducted in a laboratory geared to this work; hence all fluoride samples were shipped in polyethylene bottles to the Florida State Board of Health's Air Pollution Laboratory in Winter Haven for analysis.

To compare methods of fluoride sampling, one Greenberg-Smith impinger and a sodium bicarbonate coated tube sampler were operated in parallel at Station A for the entire 8 days of the second phase of the industrial survey. The tube sampler is reported as an efficient method of sampling gaseous fluorides.[31] The Greenberg-Smith impinger collects both gaseous and particulate fluorides.

During Phase I, neither fertilizer plant was in production; in Phase II, both plants went on-stream. A comparison of the results of Phase I and Phase II is indicative of the effect of this specific type of industrial activity on pollution levels in the area.

Fluorides

During Phase I, 117 8-hour impinger samples were obtained in the industrial area; 120 samples were collected during Phase II. The summary of results is listed in Table 26. Individual results for Phase II are presented in Table 27.

Table 26. SUMMARY OF 8-HOUR IMPINGER SAMPLES FOR AIRBORNE FLUORIDES, JACKSONVILLE, FLORIDA, AUGUST-SEPTEMBER, 1961

Station	Phase I (8/4 - 8/12)				Phase II (9/5 - 9/13)				
	No. samples	Fluoride concentration,[a] µg/m³			No. samples	Fluoride concentrations, µg/m³			
		Avg.	Max.	Min.		Avg.	Median	Max.	Min.
A	24	1.14	2.38	0.43	24	3.90	2.79	14.12	0.57
B	24	0.97	2.16	0.07	24	0.88	0.65	4.12	0.23
C	24	0.85	1.77	0	24	0.56	0.51	1.32	0
D	24	1.79	3.21	0.62	24	0.96	0.70	3.55	0.32
E	21	0.49	1.08	0	24	1.11	0.92	3.71	0.10

[a]Because of the low concentrations, the 24 samples were composited into 8 samples, each a composite of three 8-hour samples. Median values were not computed because of the small number of composite samples.

Although three of the stations in Phase II showed decreased average concentrations, Stations A and E showed increases in average concentration by factors of 3.4 and 2.3, respectively. The maximum 8-hour total fluoride concentration was 14.12 micrograms per cubic meter, which occurred at Station A during Phase II. The difference in concentrations observed in Phases I and II is shown in Figure 12. The additional industrial activity during Phase II had a definite effect on atmospheric fluoride concentrations.

Table 27. INDICATED AIRBORNE FLUORIDE CONCENTRATIONS JACKSONVILLE, FLORIDA - SEPT. 5-13, 1961

Date	Starting time[a]	Fluoride concentration by stations,[b] $\mu g/m^3$				
		A	B	C	D	E
9/5/61	0800	0.57	0.41	0.76	0.91	1.63
	1600	1.90	1.06	0	2.43	0.52
	2400	0.67	0.65	0.45	0.35	0.10
9/6/61	0800	1.57	0.31	0.40	0.32	0.93
	1600	1.50	0.80	0.69	0.56	0.10
	2400	2.59	0.23	0.27	0.49	3.71
9/7/61	0800	4.54	0.45	1.32	0.62	1.20
	1600	1.44	1.19	0.67	1.09	1.23
	2400	1.11	0.64	0.19	0.33	2.45
9/8/61	0800	2.14	0.55	0.76	0.69	0.91
	1600	4.36	0.86	0.48	1.47	0.90
	2400	1.97	0.69	0.15	1.44	1.12
9/9/61	0800	2.48	1.40	1.08	0.80	1.19
	1600	4.81	0.50	1.01	0.72	1.90
	2400	2.96	2.13	0.46	0.51	0.39
9/10/61	0800	5.10	0.59	0.19	1.10	2.12
	1600	6.75	0.91	0.35	1.45	0.47
	2400	10.64	4.12	0.53	0.60	1.75
9/11/61	0800	6.97	0.63	0	0.59	0.77
	1600	5.62	0.33	0.49	3.55	0.36
	2400	2.43	0.47	0.76	1.37	1.87
9/12/61	0800	14.12	0.76	1.08	0.76	0.52
	1600	4.27	0.92	0.62	0.52	0.32
	2400	2.62	0.49	0.80	0.42	0.12

[a]All samples started within 15 minutes of indicated starting time.
[b]Figure 10.

To determine the fraction of the total airborne fluoride that was gaseous and that which was particulate a sodium bicarbonate coated tube sampler[31] was operated at Station A for the full period of Phase II. The "gaseous" sampler indicated an average fluoride concentration of 2.10 micrograms per cubic meter. A comparison with the average concentration of total fluorides for this period at Station A indicates that about half of the airborne fluorides were in the gaseous state.

According to Adams, Applegate, and Hendrix[32] a hydrogen fluoride concentration of 10 parts per thousand million (pptm) (7.8 $\mu g/m^3$) for approximately 14 hours, and 5 pptm (3.4 $\mu g/m^3$) for 24 hours (three - 8-hour fumigations in daylight) caused

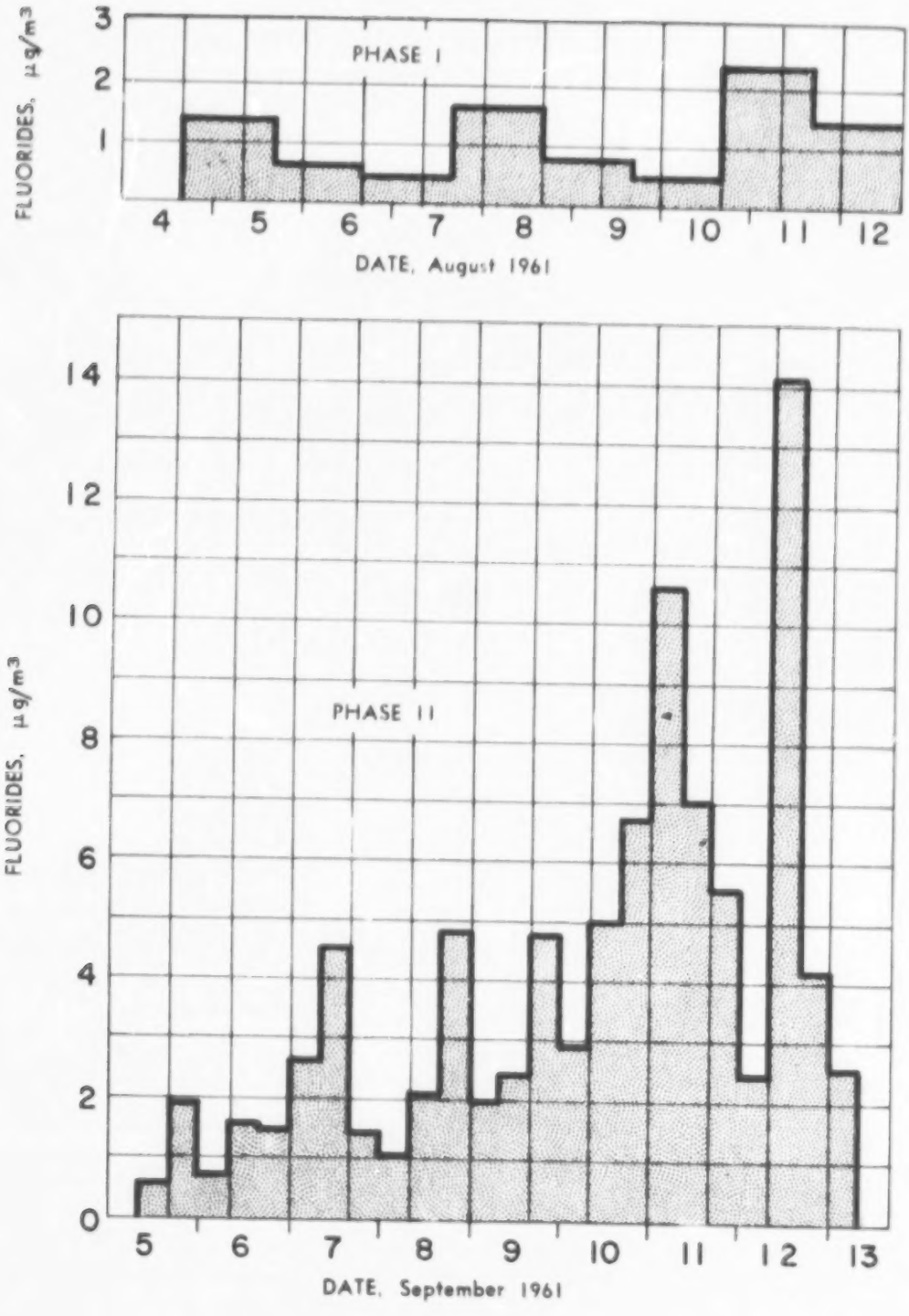

Figure 12. Station A. Airborne fluoride concentrations, August 4-12, 1961, and September 5-13, 1961.

incipient foliar injury to gladioli. These findings are in agreement with those of other investigators.[33]

It is concluded from these data that fluoride concentrations, at Station A at least, were high enough to cause damage to sensitive vegetation under proper growing conditions.

The data shown in Table 27 were analyzed as to frequency of occurrence of maximum, second highest, and minimum concentrations at each station during each run. The results of this analysis are shown in Table 28. In 20 of the 24 runs during

Table 28. FREQUENCY OF OCCURRENCE OF MAXIMUM, SECOND-HIGHEST, OR MINIMUM FLUORIDE CONCENTRATIONS - JACKSONVILLE, FLORIDA - SEPTEMBER 5-13, 1961

Station[a]	Maximum concentration	2nd-highest concentration	Minimum concentration
A	20	3	0
B	0	6	8
C	0	3	9
D	1	5	1
E	3	7	6

[a]Figure 10.

Phase II, samples from Station A indicated the highest concentration. Stations D and E indicated maximum concentration on 1 and 3 of the runs, respectively. During the three runs in which Station A was second highest, Stations D and E indicated maximum concentrations. Although the maximum concentrations observed during these runs were not the maximum concentrations observed during the 24 runs at Stations D and E, during Phase II transport conditions were such as to produce maximum concentrations at site D and across the St. John's River at site E at certain times. This occurred on September 5, 6, and 7, which were not times of maximum production of fluorides during this phase. It can, therefore, be concluded that at times of full plant production, with meteorological conditions similar to those that produced the maximum series concentrations at Station D and E, concentrations of fluorides much higher than those observed in this study can be expected to occur at Stations D and E. Figures 1 and 2 graphically show wind movements from the northwest transporting pollutants across the river from Jacksonville. Figures 13 and 14, taken one hour apart during Phase I, demonstrate variability of wind movement within a very limited time.

Figure 13. Looking northerly from Sampling Site E, during Phase I of Industrial Area Investigation. Pollutants from the Jacksonville area are being carried across the St. John's River.

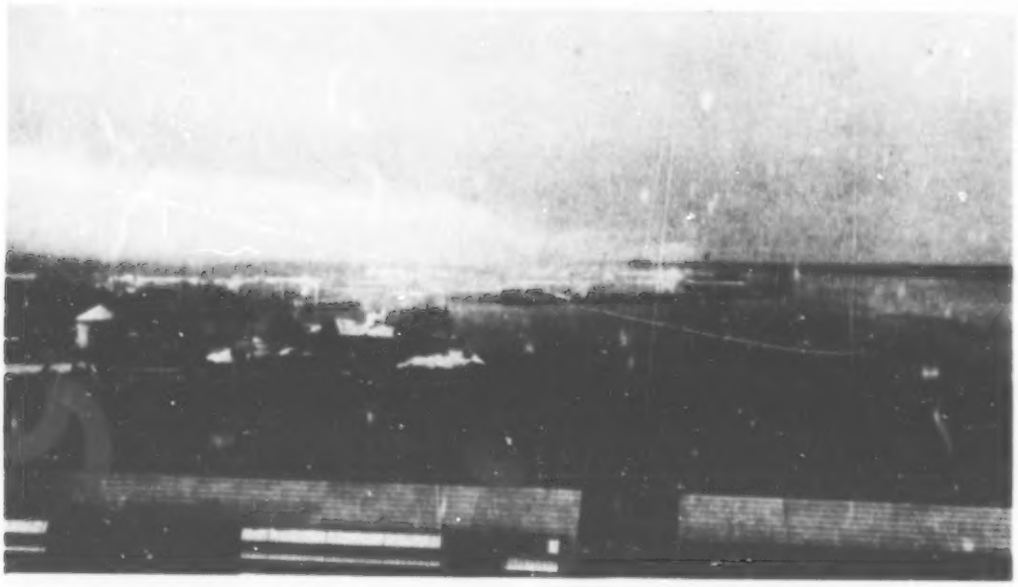

Figure 14. This picture was taken one-hour after Figure 13, from the Mathews Bridge immediately south of Station C. The pollutants are now being transported in the opposite direction.

Dustfall and Rainout

During Phase I and II, an automatic rain sampler was operated at Station A. Three samples were collected during Phase I, and 2 during Phase II. The amount of fluoride contained in these samples is listed in Table 29.

Table 29. FLUORIDES IN RAIN WATER, STATION A, JACKSONVILLE, FLORIDA - AUGUST-SEPTEMBER, 1961

Date	Fluorides in rain			Total fluoride deposition rate, $\mu g/cm^2$
	Soluble, μg	Insoluble, μg	Total, μg	
Phase I				
8/5/61	-	-	9.5	0.015
8/7/61	-	-	0	0
8/11/61	-	-	82	0.134
Phase II				
9/8/61	5.5	38.5	44	0.072
9/13/61	10.5	27	37.5	0.061

Dustfall jars were placed at each site during Phase II; both dustfall and rainout material were collected. The samples were analyzed for soluble and insoluble fluorides and total solids, and results are tabulated in Table 30. Maximum fluoride deposition occurred at Station A, where 2.27 micrograms per square centimeter was deposited during Phase II. The total deposition in the rain gage at Station A during the same period was 0.133 micrograms per square centimeter. These results indicate that approximately 6 percent of the material deposited in the dustfall jar was contributed by rainout. The ratio of the soluble to insoluble fluoride fraction of each sample has been included in Table 30.

Sulfur Dioxide

During Phase I and II, 498 analyses for sulfur dioxide were performed on samples taken at sites A, B, and C. These three stations are situated in a general north-south orientation, as are the main sources of sulfur dioxide in this area -- the power plants and the fertilizer industry (Figure 10). During Phase I, only the power plants were in operation. Table 31 summarizes results of both phases.

During Phase I, maximum sulfur dioxide concentrations were 360, 240 and 210 micrograms per cubic meter (0.137, 0.092 and 0.079 ppm) for Stations C, A, and B, respectively; during Phase II, they were 260, 140 and 97 micrograms per cubic meter (0.099, 0.054 and 0.037 ppm) for Stations A, B, and C, respectively.

In comparing the concentrations exceeded by 5 percent of the observations for each station in the two phases, it is seen

Table 30. FLUORIDE DEPOSITION RESULTS - JACKSONVILLE, FLORIDA - SEPTEMBER 5-13, 1961

Station[a]	Fluorides		Total fluorides deposited during period, % of total solids
	Total fluoride deposition rate, $\mu g/cm^2$	Ratio, Soluble F / Insoluble F	
Dustfall and rainout			
A	2.27	2.60	0.79[b]
B	0.07	0.16	0.12
C	0.37	7.50	0.48
D	c	c	c
E	0.12	10.0	0.26
F	0.08	0.16	0.14
Rainout			
A(9/8/61)	0.072	7.00	-
(9/13/61)	0.061	2.58	0.51

[a]Figure 10.
[b]Sample contained midge-larvae.
[c]Sample contaminated with water from sprinkler system at nursery.

Table 31. SUMMARY OF SULFUR DIOXIDE CONCENTRATIONS OBSERVED DURING AUGUST - SEPTEMBER, 1961, JACKSONVILLE, FLORIDA

Station[a]	Period (1961)	No. of samples	Indicated sulfur dioxide concentration							
			Min.		Median		Max.		95% of values equal to or less than indicated value	
			$\mu g/m^3$	ppm[b]	$\mu g/m^3$	ppm[b]	$\mu g/m^3$	ppm[b]	$\mu g/m^3$	ppm[b]
A	8/4 - 8/12	61	0	0[c]	7.1	0.003	240.	0.092	52.	0.030
	9/5 - 9/13	96	0	0	9.5	0.004	260.	0.099	140.	0.053
B	8/4 - 8/12	67	0	0	7.1	0.003	210.	0.079	120.	0.047
	9/5 - 9/13	96	0	0	3.6	0.001	140.	0.054	59.	0.022
C	8/4 - 8/12	83	0	0	4.8	0.002	360.	0.137	130.	0.050
	9/5 - 9/13	95	0	0	3.6	0.001	97.	0.037	19.	0.007

[a]Figure 10.
[b]Parts per million calculated from $\mu g/m^3$, assuming that pollutant determined in the analysis existed as a gas in the ambient air.
[c]0 indicates below detectable limit.

that this value for Stations B and C decreased from Phase I to Phase II, while it increased for Station A. This increase at Station A from 52 micrograms per cubic meter (0.020 ppm) to 140 micrograms per cubic meter (0.053 ppm) may be an indication of the effect of the fertilizer industry's sulfuric acid plants on the environment. (These plants were inoperative during Phase I.)

The data collected at Station A during Phase I and II are presented on arithmetic probability paper in Figures 15 and 16, respectively. With the exception of the maximum value obtained during Phase I, Figure 15 exhibits a pattern of two statistically normal distributions superimposed on each other.

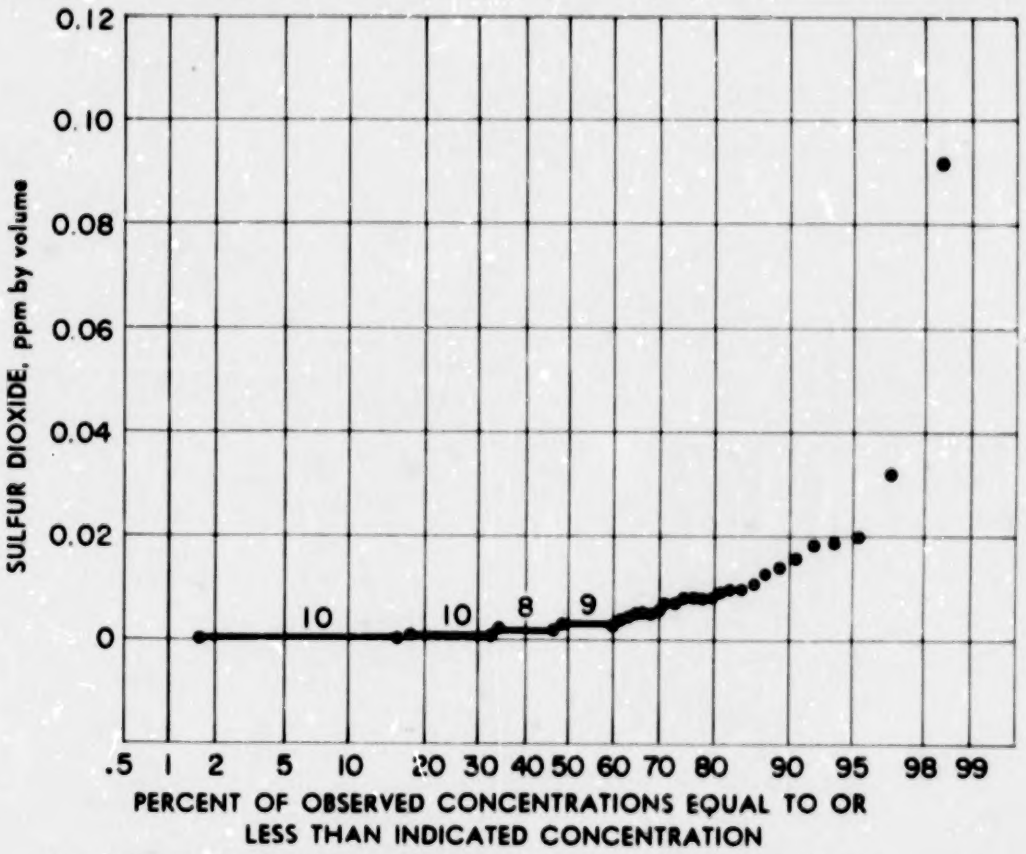

Figure 15. Distribution of observed sulfur dioxide concentration at Station A, Phase I.

Figure 16, however, exhibits a pattern of three normal distributions. These patterns could have been due to the influence of wind direction on transport of pollution from source to sampling site. During Phase I, the pattern might have been a result of east-west, and north-south wind movement; Phase II's pattern might have resulted from a western, north-south and easterly movement of air. The higher concentrations probably occurred with an easterly wind direction as the sampling site was located in a westerly direction from the sulfuric acid plants operating during Phase II.

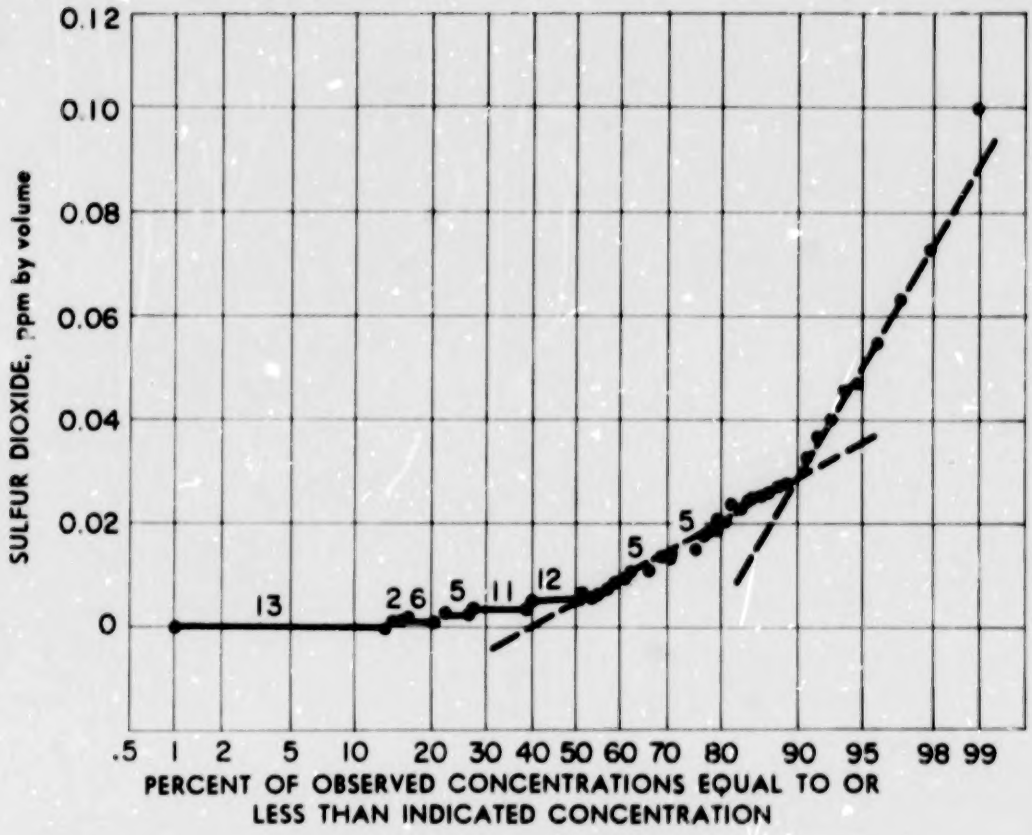

Figure 16. Distribution of observed sulfur dioxide concentration at Station A, Phase II.

An attempt was made to correlate wind direction measurements made at the U. S. Weather Bureau Station at Imeson Airport and the Naval Air Station with sulfur dioxide concentrations observed during Phase II. The concentrations selected were those that fell in the highest 10 percent of the data obtained for Phase II at Station A. The wind directions for these concentra-

Table 32. WIND DIRECTIONS OBSERVED AT U. S. WEATHER BUREAU STATION AND THE NAVAL AIR STATION, JACKSONVILLE, FLORIDA, FOR THE 10 HIGHEST SULFUR DIOXIDE CONCENTRATIONS AT STATION A, IN PHASE II

Wind direction	Number of occurrences	
	Imeson Airport, USWB	Naval Air Station
NNW-NE	2	3
ENE-SE	8	7
SSE-SW	0	0
WSW-NW	0	0

tions are shown in Table 32. The hypothesis mentioned above seems to be borne out by this analysis. The results indicate that this type of analysis would produce more conclusive results if more appropriate meteorological measurements were made in the area under study, because of the variables involved.

Nitrogen Dioxide

During Phase II, 97 analyses for nitrogen dioxide were made on samples collected at Station A. The distribution of results is shown in Figure 17. Concentrations ranged from 0 to 300 micrograms per cubic meter (0.159 ppm), the median concentration being 27 micrograms per cubic meter (0.014 ppm). The first

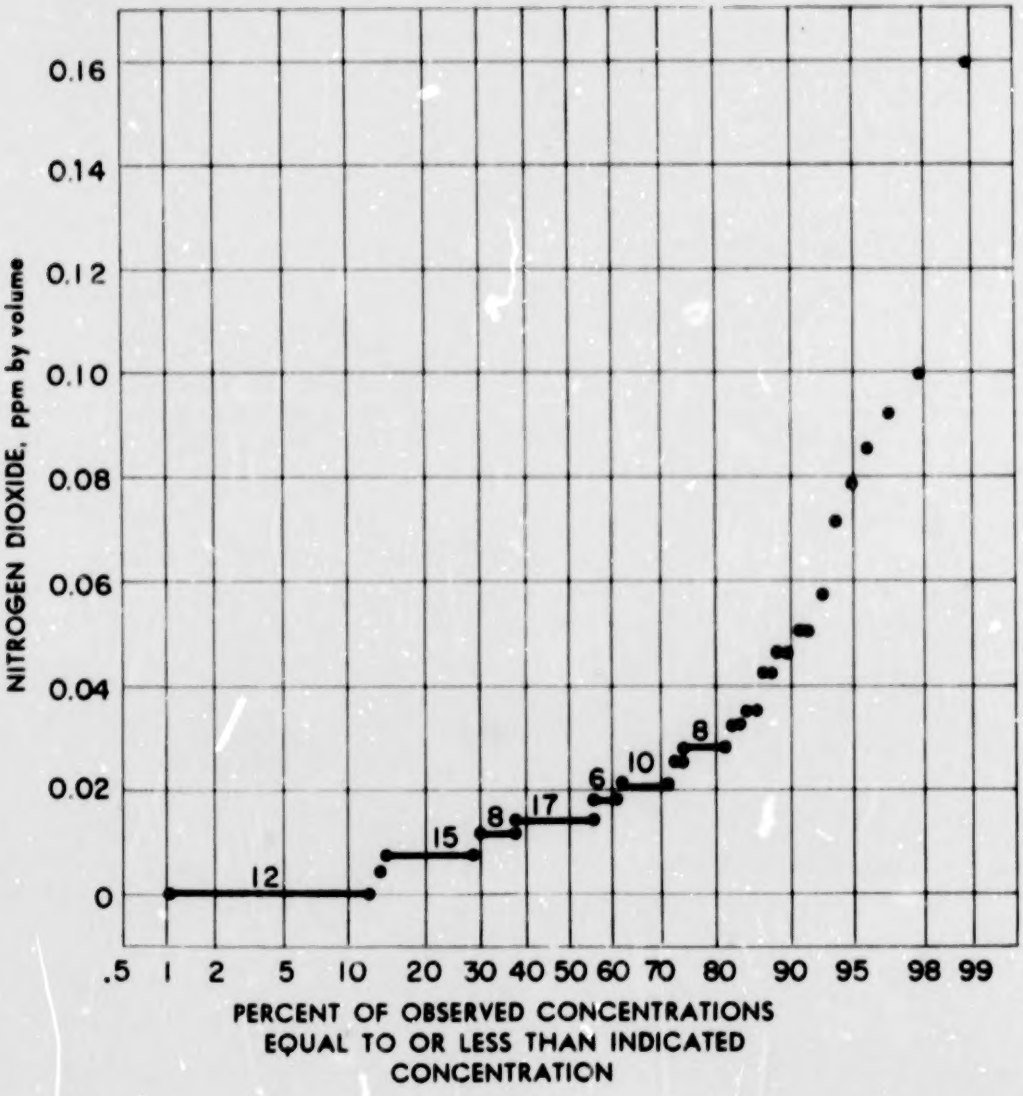

Figure 17. Distribution of observed nitrogen dioxide concentration at Station A, Phase II.

half of this distribution is very similar to that observed during Phase I at the Hemming Park Site (Figure 6); the second half consists of higher concentrations, which may be indicative of the nitrogen dioxide contributed by the industrial activity in this area. Further study of this pollutant has to be carried out concurrently with a detailed micrometeorological study before this indication can be proven.

Hydrogen Sulfide

During Phases I and II, 576 2-hour lead acetate-impregnated tape samples were obtained at Stations B, C, and F for determination of hydrogen sulfide. The results are summarized in Table 33. Some doubt exists as to whether the concentrations indicated by these samples are quantitative. At numerous times, the odor of hydrogen sulfide was observed at these stations. The accepted odor threshold for this pollutant

Table 33. SUMMARY OF INDICATED HYDROGEN SULFIDE CONCENTRATIONS, AUGUST 4-12 AND SEPTEMBER 5-13, 1961 - JACKSONVILLE, FLORIDA

Station[a]	Dates (1961)	No. of samples	Hydrogen sulfide concentration, ppm			
			Mean	Median	Max.	Min.
B	8/4 - 8/12 9/5 - 9/13	196	0.0014	0.001	0.008	0
C	8/4 - 8/12 9/5 - 9/13	197	0.0013	0.001	0.009	0
F	8/4 - 8/12 9/5 - 9/13	183	0.0011	0.001	0.004	0

[a]Figure 10.

is 0.025 to 0.10 ppm. In view of this, no interpretation of these data has been made. It is apparent from the data, however, that hydrogen sulfide was present during this study. It is suggested that in future studies of this pollutant, parallel sampling should be conducted with a tape sampler and the bubbler-type collector method suggested by Bender and Jacobs.[34]

ACKNOWLEDGMENTS

This study could not have been carried out without the close cooperation of private individuals, industrial organizations, and governmental agencies. Special acknowledgment is made to the following individuals and organizations who helped materially by providing sampling sites used in this study.

Mr. Charles Bostwick	P. O. Box 164, Jacksonville
Mr. C. V. DeLettre	2240 Shepherd, Jacksonville
Mr. Glenn Marshall	WJXT, Jacksonville
Mr. Joseph M. Ripley	Jagco Inc., Jacksonville

The Jacksonville Power and Light Company provided electric power at the sampling sites. Appreciation is expressed to Mayor Hayden Burns and the members of the City Commission for their cooperation in this study. Special acknowledgment is given to Mr. Thomas Ard, Sanitary Engineer of the Jacksonville City Health Department, for his efforts during the study and for his review of the report.

Special acknowledgment is given Mrs. Billye K. Bierhorst and Misses J. B. Shepherd, C. A. Cushing, and L. A. Pitts of the Training Program of the Robert A. Taft Sanitary Engineering Center for their efforts in the preparation of this report.

Aerial photographs were provided by the U. S. Coast and Geodetic Survey.

GPO 802-899-5

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APPENDIX

FLORIDA STATE BOARD OF HEALTH
JACKSONVILLE, FLORIDA

INVENTORY OF AIR POLLUTION EMISSIONS
INDUSTRIAL SOURCES

Firm Name: _____

Address: _____ County: _____

Plant representative to be contacted on air pollution matters: _____ Title: _____

Normal operating schedule: _____ hrs. per day ____ days per year.

Total number of employees: _____.

Principal materials processed or used (types and amounts per day): _____

_____

_____

_____

PROCESS EMISSIONS

Operations which are exhausted or release contaminants to outside air[1]	Materials Produced and/or used at operation[2]	Quantity of exhaust (cfm)	Control equipment (if any)[3]	Dust, fume gas, etc. exhausted		Basis of Estimate[6]
				Type[4]	Quantity[5]	

(Use additional sheets of paper where necessary)

[1]Examples: casting, cleaning, spray painting, degreasing, iron-melting, cupola, etc.

[2]Examples: 10 tons per day iron castings cleaned, 10 gals per day solvent used, 2000 bbl per day cement produced, 600 tons/d wood pulp produced, etc.

[3]Examples: electrostatic precipitator, cyclone, settling chamber, wet scrubber, baghouse, etc.

[4]Iron oxide & silica dusts, trichlorethylene, formaldehyde, SO_2, HCN, etc.

[5]Lbs. per day, tons per month, or other convenient units, if known.

[6]Assumption, material balance, tests by plant personnel or equipment manufacturer, etc.

NOTE: Any supplemental material or data considered pertinent (as reports, summaries, test results, maps and flow diagrams) may be attached and would be appreciated. Attach additional report sheets, as necessary.

Fuel Combustion Emissions

Is the firm the only occupant of the factory building in which it is located? (yes, no)

Does the firm have its own heating plant or other combustion equipment? (yes, no)

If the answer to either of the above questions is Yes, please complete the FUEL CONSUMPTION DATA below.

If the answers to the above questions are No, please indicate from whom the FUEL CONSUMPTION DATA may be obtained.

FUEL CONSUMPTION DATA

Fuel[1]	Type[2]	Amount[3]	Percent sulfur (if known)

[1]Examples: Coal, coke, fuel oil, gas, etc.
[2]Examples: Pa. anthracite, W. Va. bituminous, No. 5 fuel oil, natural gas, etc.
[3]Examples: Tons per year, gallons per day, cubic feet per month, or other convenient units.

WASTES AND SALVAGE-OPERATION COMBUSTION

Types and amounts of waste materials burned (e.g. 10 cu. ft. per day of paper, 3 bu. per day of sawdust and wood scraps, 2 tons mixed refuse per month, etc.):

Method of burning (e.g. open dump, incinerator, salvage-process burner, etc.):

Date:_____ Reported by:_____

Manufacturing or Product Description	Process	Composition	Type (1)
Grey Iron Foundries	Melting in Cupola	Iron Oxide	P
	Sand Handling	Sand	P
	Pouring & Core Baking	Acrolein	G
	Chipping & Grinding	Iron & Abrasive	P
	Shot Blast	Steel & Sand	P
	Sand Blast	Sand	P
	Galvanizing	ZnO, $ZnCl_2$	F
Machine Shops	Grinding	Abrasive & Steel	P
	Welding	Iron Oxide	F
	Silver Solder	Ag, Cu, Zn	F
	Shot Blast	Steel & Sand	P
	Bright Dip	CrO_3	M
	Degreasing	Trichlor	G
Galvanizing	Acid Dip	H_2SO_4	M
	Fluxing	NH_4Cl	F
	Zinc Bath	ZnO	F
Misc. Manufacturing	Spray Painting	Thinner	G
	Woodworking	Wood	P
	Distillation	Thinner	G
	Plastic Molding	Phenol Formaldehyde	G
	Plastic Coating	Monochlorbenzene	G
		Naphtha	G
	Garnet Mach	Cotton	P
	Degreasing	Trichlor	G
	Coil Lacquer	Thinner	G
	Welding	Iron Oxide	F
	Polishing	Abrasive, Steel	P
	Gluing	Thinner	G
		Formaldehyde	G
	Sand Blast	Sand	P
	Shot Blast	Steel	P
	Grinding	Abrasive, Steel	P
	Lead Coating	Lead Oxide	F
	Degreasing	Chlorethene	G
	Soldering	Ag, Cu	F
	Degreasing	Perchlor	G
	Gluing	Toluene	G
Gasoline & Oil Storage	Gasoline Hand.	Gasoline	G
	Fuel Oil Hand.	Oil	G

(1) G-Gas; P-Particulate; F-Fume; M-Mist

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